EFFECT OF POZZOLANAS ON FIBER REINFORCED CONCRETE

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Technology
in
Civil Engineering

By

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DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA-769008,
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CERTIFICATE

This is to certify that project review report entitled, **"EFFECT OF POZZOLANAS ON FIBER REINFORCED CONCRETE"** submitted by **ASHISH KUMAR DASH** in partial fulfillment of the requirements for the award of **Master of Technology** Degree in **Civil Engineering** with specialization in **Structural Engineering** at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in this Project review report has not been submitted to any other university/ institute for award of any Degree or Diploma.

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ABSTRACT

High-performance concrete is defined as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large-scale concrete construction that demands high strength, high flowability, and high durability. A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfill all of the properties. So the different pozzolanic materials like Ground Granulated Blast furnace Slag (GGBS), silica fume, Rice husk ash, Fly ash, High Reactive Metakaolin, are some of the pozzolanic materials which can be used in concrete as partial replacement of cement, which are very essential ingredients to produce high performance concrete. So we have performed XRD tests of these above mentioned materials to know the variation of different constituent within it. Also it is very important to maintain the water cement ratio within the minimal range, for that we have to use the water reducing admixture i.e superplasticizer, which plays an important role for the production of high performance concrete. So we herein the project have tested on different materials like rice husk ash, Ground granulated blast furnace slag, silica fume to obtain the desired needs. Also X-ray diffraction test was conducted on different pozzolanic material used to analyse their content ingredients. We used synthetic fiber (i.e Recron fibe) in different percentage i.e 0.0%, 0.1%, 0.2%, 0.3% to that of total weight of concrete and casting was done. Finally we used different percentage of silica fume with the replacement of cement keeping constant fiber content and concrete was casted. In our study it was used two types of cement, Portland slag cement and ordinary Portland cement. We prepared mortar, cubes, cylinder, prism and finally compressive test, splitting test, flexural test are conducted. Finally porosity and permeability test conducted. Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a large number of trial mixes are required to select the desired combination of materials that meets special performance.

LIST OF SYMBOLS:

OPC	Ordinary Portland cement
HPC	High performance concrete
HSD	High strength rebars with surface deformation
HRM	High reactive Metakaoline
GGBS	Ground granulated blast furnace slag
SF	Silica fume
RHA	Rice husk ash
SNF	Sulphonated naphthaline formaldehyde
SMF	Sulphonated melamine formaldehyde
AP	Acrylic polymer
CWS	Cold water saturation
BWS	Boiling water saturation
VAS	Vacuum saturation
HRWRA	High range water reducing admixture
RC	Reinforced concrete
FRC	Fiber reinforced concrete
C	Compressive strength
S	Splitting tensile strength
F	Flexural strength
P	Load in Newton
l	Length of specimen

d	Diameter of specimen
b	Breadth of specimen
h	Height of Specimen
W	Amount of water absorbed in gm
A	Area of Specimen in contact with water
t	time in second
W_{sat}	Saturated weight
W_{dry}	Dry weight
W_w	Weight of water absorbed
Vv	Volume of voids
V	Total volume of specimen

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CHAPTER- 1

INTRODUCTION

1.1. Introduction:

Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape hardens into a rock-like mass known as concrete. The hardening is because of chemical reaction between water and cement, which continues for long period leading to stronger with age. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with ordinary portland cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials (whatever may be their qualities) of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred contempt. Strength was emphasized without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained momentum on its path to self– destruction. This is particularly true of concrete structures which were constructed since 1970 or thereabout by which time (a) the use of high strength rebars with surface deformations (HSD) started becoming common, (b) significant changes in the constituents and properties of cement were initiated, and (c) engineers started using supplementary cementitious materials and admixtures in concrete, often without adequate consideration.

The setback in the health of newly constructed concrete structures prompted the most direct and unquestionable evidence of the last two/three decades on the service life performance of our constructions and the resulting challenge that confronts us is the alarming and unacceptable rate at which our infrastructure systems all over the world are suffering from deterioration when exposed to real environments.

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

With the passage of time to meet the demand, there was a continual quest in human being for the development of high strength and durable concrete. The history of high strength concrete is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products and structural elements in beam were cast in situ using high strength concrete. Since then the technology has come of age and concrete of the order of M60 to M120 are commonly used. Concrete of the order of M200 and above are a possibility in the laboratory conditions. The definition of high strength concretes is continually developing. In the 1950s 34N was considered high strength, and in the 1960s compressive strengths of up to 52N were being used commercially. More recently, compressive strengths approaching 138N have been used in cast-in-place buildings. The advent of prestressed concrete technology has given impetus for making concrete of high strength. In India high strength concrete is used in prestressed concrete bridges of strength from 35 MPa to 45 MPa. Presently (in 2000) Concrete strength of 75 MPa is being used for the first time in one of the flyover at Mumbai. Also in construction of containment Dome at Kaiga power project used HPC of 60MPa with silica fume as one of the constituent.

The reasons for these demands are many, but as engineers, we need to think about the durability aspects of the structures using these materials. With long term durability aspects kept aside we have been able to fulfil the needs. The concrete of these properties will have a peculiar Rheological behaviour.

Now a day the construction industry turning towards pre-cast elements and requirement of post-tensioning has made the requirement of the high strength of concrete invariable and the engineers had to overcome these drawbacks, which to a great extent we have been able to do. The construction today is to achieve savings in construction work. This has now turned into one of the basic requirement of concreting process.

1.2. HIGH PERFORMANCE CONCRETE:

In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. A commentary to the definition states that a high-performance concrete is one in which certain characteristics are developed for a particular application and environment. Examples of characteristics that may be considered critical for an application are:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments

Because many characteristics of high-performance concrete are interrelated, a change in one usually results in changes in one or more of the other characteristics. A high-performance concrete is something more than is achieved on a routine basis and involves a specification that often requires the concrete to meet several criteria. For example, on the Lacey V. Murrow floating bridge in Washington State, the concrete was specified to meet compressive strength, shrinkage and permeability requirements. The latter two requirements controlled the mix proportions so that the actual strength was well in excess of the specified strength. This occurred because of the interrelation between the three characteristics.

A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. ACI defines a high-strength concrete as concrete that has a specified compressive strength for design of 6,000 psi (41

MPa) or greater. Other countries also specify a maximum compressive strength, whereas the ACI definition is open-ended.

The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure. The same is not always true for a concrete whose primary requirement is durability.

Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. In addition to requiring a minimum strength, concrete that needs to be durable must have other characteristics specified to ensure durability. In the past, durable concrete was obtained by specifying air content, minimum cement content and maximum water-cement ratio. Today, performance characteristics may include permeability, deicer scaling resistance, freeze-thaw resistance, abrasion resistance or any combination of these characteristics. Given that the required durability characteristics are more difficult to define than strength characteristics, specifications often use a combination of performance and prescriptive requirements, such as permeability and a maximum water-cementitious material ratio to achieve a durable concrete. The end result may be a high-strength concrete, but this only comes as a by-product of requiring a durable concrete.

Concrete materials most high-performance concretes produced today contain materials in addition to Portland cement to help achieve the compressive strength or durability performance. These materials include fly ash, silica fume and ground-granulated blast furnace slag used separately or in combination. At the same time, chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

Most high-performance concretes have a high cementitious content and a water-cementitious material ratio of 0.40 or less. However, the proportions of the individual constituents vary depending on local preferences and local materials. Mix proportions developed in one part of the country do not necessarily work in a different location. Many trial batches are usually necessary before a successful mix is developed. High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. Variations in the chemical and physical properties of the cementitious materials and chemical admixtures need to be carefully monitored. Substitutions of alternate materials can result in changes in the performance characteristics that may not be acceptable for high-performance concrete. This means that a greater degree of quality control is required for the successful production of high-performance concrete.

Salient Features of HPC:

- High Compressive strength
- Low water-binder ratio
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content
- Endogenous shrinkage
- Powerful confinement of aggregates
- Little micro-cracking until about 65-70% of fck
- Smooth fracture surface

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

Considering the grade of cements high strength of cement of grades 43 & 53 are desirable for design of High strength concretes. To achieve the quest of high performance concrete we should accentuate on the replacement of OPC with industrial by-products. The utilization of pozzolanic materials in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvements in the long-term durability of concrete combined with ecological benefits. Fly ash (a waste product from coal thermal power plant), ground granulated blast furnace slag, silica fumes (a waste by-product of the manufacture of Silicon or Ferro-silicon alloys from high purity quartz and coal in a submerged-arc electric furnace), rice husk ash (waste by-product from co-generation electric power plant burning rice husk), high reactive metakaoline (HRM) as partial replacement for cement which are largely available in India. To study the effect of partial replacement of cement by these pozzolanic materials, studies have been conducted on concrete mixes with 350 to 500 kg/cum cementitious material at 30%, 40%, and 50% replacement levels of fly ash; 50% and 60% replacement levels of GGBS and 7.5% and 10% replacement levels of HRM.

1.3. High Strength Concrete:

- To put the concrete into service at much earlier age, for example opening the pavement at 3-days.
- To build high-rise buildings by reducing column sizes and increasing available space.
- To build the superstructure of long span bridges and to enhance the durability of bridge decks.
- To satisfy the specific needs of special applications, such as durability, modulus of elasticity and flexural strength. Some of these applications include dams, grandstand roofs, marine foundations, parking garages and heavy duty industrial floors.(Note that high strength concrete does not guarantee durable concrete).

High-strength concrete columns can hold more weight and therefore be made slimmer than regular strength concrete columns, which allows for more useable space, especially in the lower floors of buildings. High-strength concrete is specified where reduced weight is important or where architectural considerations call for small support elements. By carrying loads more efficiently than normal-strength concrete, high-strength concrete also reduces the total amount of material placed and lower the overall cost of the structure.

There are special method of making high strength concrete such that,

- **Seeding**
- **Revibration**
- **High speed slurry mixing**
- **Use of admixtures**
- **Inhibition of cracks**
- **Sulphur impregnation**
- **Use of cementitious aggregate**

Seeding: This involves adding a small percentage of finely ground, fully hydrated Portland cement to the fresh concrete mix. This method may not hold much promise.

Revibration: Concrete under goes plastic shrinkage. Mixing water creates continuous capillary channels, bleeding and water accumulates at some selected places reducing strength of concrete. Controlled revibration removes all these defects and increases the strength of concrete.

High speed slurry mixing: It involves the advanced preparation of cement water mixer which is then blended with aggregate to produce concrete. Higher compressive strength obtained is attributed to more efficient hydration of cement particle and water achieved in the vigorous blending of cement paste.

Use of admixtures: Use of water reducing agents are known to produce increase compressive strength.

Inhibition of cracks: Replacement of 2-3% of fine aggregate by polythene or polystyrene "lentcules" 0.025 mm thick and 3-4 mm in diameter results in higher strength. They appear to acts as crack arresters without requiring extra water for workability.

Sulphur impregnation: Satisfactory high strength concrete have been produced by impregnating low strength porous concrete by sulphur. The process consist of moist curing the fresh concrete specimen for 24 hours, drying them at 120^0 C for 24 hours, immersing the specimen in molten sulphur under vacuum for 2 hrs and then releasing the vacuum and soaking them for an additional hour for further infiltration of sulphur. The sulphur infiltrated concrete has given strength up to 58 MPa.

Use of cementitious aggregates: It has been found that use of cementitious aggregate has yielded high strength. Cement fondu is a kind of clinker. This glassy clinker when finely ground results in a kind of cement. When coarsely crushed, it makes a kind of aggregate known as 'ALAG'. Using ALAG as aggregate strength up to 125 MPa has been obtained with w/c ratio 0.32.

CHAPTER- 2

REVIEW OF LITERATURE

2.1. Introduction:

As our aim is to develop concrete which does not only concern on the strength of concrete, it also having many other aspects to be satisfied like less porous, capillary absorption, durability. So for this we need to go for the addition of pozzolanic materials along with superplasticizer with having low water cement ratio. The use of silica fume is many, which is having good pozolanic activity and is a good material for the production high performance concrete. Also now a days one of the great application in various structural field is fiber reinforced concrete, which is getting popularity because of its positive effect on various properties of concrete.

2.2. Earlier researches:

Some of the early research works had done using different pozzolanic materials with the replacement of cement using superplasticizer for the development high performance concrete. Also the development in the field of fiber reinforced concrete along with pozzolanas. So below an over view of different studies has been represented.

Aitcin[1] (1995) cited on development in the application of high performance concrete. Over the last few years, the compressive strength of some of the concrete used has increased dramatically. In 1988, a 120 MPa concrete was delivered on site, while, until relatively recently, 40 MPa was considered indicative of high strength. The spectacular increase in compressive strength is directly related to a number of recent technological developments, in particular the discovery of the extraordinary dispersing action of superplasticizers with which flowing concretes can be made with about the same mixing water that is actually required to hydrate all the cement particles or even less. The reduction in water/cement ratio results in a hydrated cement paste with a microstructure so dense and strong that coarse aggregate can become the concrete's weakest constituent. Silica fume, a highly reactive pozzolana, considerably enhances the paste/aggregate interface and minimizes debonding. Lastly, the use of supplementary cementitious materials, such as fly ash and especially slag, helps solve slump loss problems which become critical at low w/c ratios.

Ajdukiewicz and Radomski[2] (2002) delve into Trends in the Polish research on high-performance concrete. They analysed the main trends in the research on high-performance concrete (HPC) in Poland. There they sighted on some examples of the relevant investigations. The fundamental engineering and economical problems concerning the structural applications of HPC in Poland are presented as well as the needs justifying the increased use of this material are briefly described.

Aitcin[3] (2003) studied on the durability characteristics of high performance concrete. He examined durability problems of ordinary concrete can be associated with the severity of the environment and the use of inappropriate high water/binder ratios. High-performance concrete that have a water/binder ratio between 0.30 and 0.40 are usually more durable than ordinary concrete not only because they are less porous, but also because their capillary and pore networks are somewhat disconnected due to the development of self-desiccation. In high-performance concrete (HPC), the penetration of aggressive agents is quite difficult and only superficial. However, self-desiccation can be very harmful if it is not controlled during the early phase of the development of hydration reaction, therefore, HPC must be cured quite differently from ordinary concrete. Field experience in the North Sea and in Canada has shown that HPCs, when they are properly designed and cured, perform satisfactorily in very harsh environments. However, the fire resistance of HPC is not as good as that of ordinary concrete but not as bad as is sometimes written in a few pessimistic reports. Concrete, whatever its type, remains a safe material, from a fire resistance point of view, when compared to other building materials.

Al-Khalaf and A. Yousif [4] (1984) examined on use of RHA in concrete. They studied the actual range of temperature require to burn rice husk in order to get the desired pozzolanic product, use of rice husk as partial replacement of cement on compressive strength and volume changes of different mixes. And showed that up to 40% replacement can be made with no significant change in compressive strength compared with the control mix. He tested on mortar cube, by testing on 50 mm cubes. In his investigation alsohe deduced that the most convenient and economical burning conditions required to convert rice husks into a homogenous and well burnt ash is at 500^0 C for 2 hours. Also for a given grinding time, there is a considerable reduction in the specific surface area of RHA as burning temperature increases. For mortar mix with constant RHA content, the water requirement decreases as the fineness of the ash increases. The minimum pozzolanic activity can be obtained, when the ash has a specific surface of about 11,500 cm^2/gm. The strength of cement-RHA mortar approaches the strength of the corresponding plain mortar when the specific surface of RHA about 17000cm^2/gm. For 1:2 and 1:3 mortar mixes of standard consistency the maximum percentage of rice husk ash that can be replaced by weight of cement without 60 days strength being less than that of plain mortar was 30% and 40 % respectively. Also he found higher the percentage or RHA, higher is the volume change characteristic corresponding to plain mortar.

Ismail and waliuddin[5] (1996) had worked on effect of rice husk ash on high strength concrete. They studied the effect of rice husk ash (RHA) passing 200 and 325 micron sieves with l0-30% replacement of cement on the strength of HSC. The RHA was obtained by burning rice husk, an agro-waste material which is abundantly available in the developing countries. A total of 200 test specimens casted and tested at 3,7,28 and 150 days. Compressive and split tensile strengths of the test specimens.Cube strength over 70 MPa was obtained without any replacement of cement by RHA. Test results indicated that strength of HSC decreased when cement was partially replaced by RHA for maintaining same level of workability. They observed that optimum replacement of cement by RHA was 10-20%, and even from crystalline form of RHA good result may be obtained by fine grinding.

De Sensale[6] (2006) studied on strength development of concrete using rice husk ash. This paper presents a study on the development of compressive strength up to 91 days of concretes with rice-husk ash (RHA), in which residual RHA from a rice paddy milling industry in Uruguay and RHA produced by controlled incineration from the USA were used for comparison. Two different replacement percentages of cement by RHA, 10% and 20%, and three different water/cementicious material ratios (0.50, 0.40 and 0.32), were used. The results are compared with those of the concrete without RHA, with splitting tensile strength and air permeability. It is concluded that residual RHA provides a positive effect on the compressive strength at early ages, but the long term behavior of the concretes with RHA produced by controlled incineration was more significant. Results of splitting tensile and air permeability reveal the significance of the filler and pozzolanic effect for the concretes with residual RHA and RHA produced by controlled incineration.

Oner A and Akyuz S [7] (2007) studied on optimum level of ground granulated blast furnace slag (GGBS) on compressive strength of concrete. In their study GGBS was added according to the partial replacement method in all mixtures. A total of 32 mixtures were prepared in four groups according to their binder content. Eight mixes were prepared as control mixtures with 175, 210, 245 and 280 kg/m3 cement content in order to calculate the Bolomey and Feret coefficients (KB, KF). For each group 175, 210, 245 and 280 kg/m3 dosages were determined as initial dosages, which were obtained by removing 30 percent of the cement content of control concretes with 250, 300, 350, and 400 kg/m3 dosages. Test concretes were obtained by adding GGBS to concretes in an amount equivalent to approximately 0%, 15%, 30%, 50%, 70%, 90% and 110% of cement contents of control concretes with 250, 300, 350 and 400 kg/m3 dosages. All specimens were moist cured for 7, 14, 28, 63, 119, 180 and 365 days before compressive strength testing. The test results proved that the compressive strength of concrete mixtures containing GGBS increases as the amount of GGBS increase. After an optimum point, at around 55% of the total binder content, the addition of GGBS does not improve the compressive strength. This can be explained by the presence of unreacted GGBS, acting as a filler material in the paste.

It was found that as the GGBS content increases, the water-to-binder ratio decreases for the same workability. The early strength of GGBS concrete was lower than that of the control concrete. However, as the curing period is extended the strength increase was higer for GGBS concrete.The compressive strength of GGBS concrete increases as the GGBS content is increased up to an optimum point, after which the compressive strength decreases. The optimum level of GGBS content for maximizing strength is at about 55–59% of the total binder content.

Qian Jueshi and Shi Caijun [8] (2000) studied on high performance cementing materials from industrial slag. They found most industrial slags are being used without taking full advantage of their properties or disposed rather than used. The industrial slags, which have cementitious or pozzolanic properties, should be used as partial or full replacement for Portland cement rather than as bulk aggregates or ballasts because of the high cost of Portland cement, which is attributable to the high energy consumption for the production of Portland cement. The traditional way to utilize metallurgical slags in cementing materials is to partially replace Portland cement, which usually results in a lower early strength and longer setting times. Presence of activator(s) can accelerate the break-up of structure and hydration of slags. Many research results have indicated that clinkerless alkali-activated slags even exhibit higher strengths, denser structure and better durability compared with Portland cement. In this paper, the recent achievements in the development of high performance cementing materials based on activated slags such as blast furnace slag, steel slag, copper slag and phosphorus slag are reviewed.

Here they reviewed the recent progresses in the activation of latent cementitious properties of different slag. Alkali-activated slag, such as blast furnace slag, steel slag, copper slag and phosphorus slag exhibit not only higher early and later strength, but also better corrosion resistance than normal Portland cement. The production of Portland cement is an energy-intensive process, while the grinding of metallurgical slag needs only approximately 10% of the energy required for the production of Portland cement. Activation of latent pozzolanic or cementitious properties of metallurgical slag should be a prime topic for construction materials researchers.

Ganesh Babu K and Sree Rama Kumar V[9] (2000) studied on efficiency of GGBS in Concrete. According to them the utilisation of supplementary cementitious materials is well accepted because of the several improvements possible in the concrete composites and due to the overall economy. This method recognises that the ``overall strength efficiency factor (k)" of the pozzolan is a combination of the two factors-the ``general efficiency factor (ke)" and the ``percentage efficiency factor (kp). The evaluations have shown that at 28days, the ``overallstrength efficiency factor (k)" varied from 1.29 to 0.70 for percentage replacement levels varying from 10% to 80%. It was also seen that the overall strength efficiency factor (k) was an algebraic sum of a constant ``general efficiency factor (ke)," with a value of 0.9 at 28 days, and a percentage efficiency factor (kp), varying from +0.39 to -0.20, for the cement replacement levels varying from 10% to 80% studied.

Collepardi[10] (1998) observed on admixture used to enhance placing charecteristics of concrete. He obserbed placing characteristics of concrete can be enhanced by using plasticizing and supelplasticizing admixtures without any change in the water-cement ratio with respect to the plain mixture. The main ingredients used in superplasticizers are based on sulfonated melamine formaldehyde (SMF) condensate or naphthalene formaldehyde (SNF) condensate. He proposed a new family of products, based on acrylic polymers (AP). These polymers are more effective than those based on SMF or SNF in terms of lower base water-cement ratio at a given slump and lower slump loss. Moreover; the effectiveness of the AP-based superplasticizers does not depend significantly on the mode of addition, whereas the slump level of concrete mixes with SMF- and SNF-based admixtures ic much higher with a delayed addition of superplasticizer with respect to that of mixing water The dispersion of cement particles responsible for the fluidity increase, caused by the superplasticizer addition, is not necessarily related to the electrostatic repulsion associated with zeta potential measurements, as it was found for SMF- and SNF-based admixtures. For the AP-based superplasticizers, the polymer adsorption, rather than the electrostatic repulsion, is responsible for the dispersion of large agglomerates of cement particles into smaller ones, which results in a remarkable increase in the fluidity of cement mixes.

Papayianni, Tsohos, Mavria[11] (2005) studied on Influence of superplasticizer type and mix design parameters on the performance of them in concrete mixtures. According to them use of superplasticizers in concrete plays a central role in the development of high strength and performance concrete. Superplasticizers are admixtures, which are added to concrete mixture in very small dosages. Their addition results in significant increase of the workability of the mixture, in reduction of water/cement ratio or even of cement quantity. Their performance depends on the type of the superplasticizer, the composition of the concrete mixture, the time of addition and the temperature conditions during mixing and concreting. They tested on three type of superplasticizer. for study the performance of the admixtures, three Dosage of admixture(1%, 1.5%, 2% per weight of cement) were checked for every type of superplasticizers in concrete casting. He casted concrete and compressive strength was observed.

Zollo[12] (1997) overviewed on fiber reinforced concrete over the 30 years of development. It discusses commonly applied terminology and models of mechanical behavior that form a basis for understanding material performance without presenting mathematical details. They reviewed properly about FRC rather than as historical reporting.

A. M. Alhozaimy, P. Soroushian & F. Mirza [13] (1996) studied on mechanical properties of polypropylene fiber reinforced concrete and the effects of pozzolanic materials. A comprehensive set of experimental data were generated regarding the effects of collated fibrillated polypropylene fibers at relatively low volume fractions (below 0.3%) on the compressive, flexural and impact properties of concrete materials with different binder compositions. Statistical analysis of results produced reliable conclusions on the mechanical properties of polypropylene fiber reinforced concrete, and also on the interaction of fibers and pozzolanic admixtures in deciding these properties. Polypropylene fibers were observed to have no statistically significant effects on compressive or flexural strength of concrete, while flexural toughness and impact resistance showed an increase in the presence of polypropylene fibers. Positive interactions were also detected between fibers and pozzolans.

He studied on the effects of collated fibrillated polypropylene fibers at volume fraction ranging from 0.05% to 0.30% on the compressive and flexural strength and toughness, and impact resistance of conventional concrete materials and concretes incorporating different pozzolanic materials experimentally. Polypropylene fibers affect the flexural toughness significantly at 95% level of confidence. On the average, the addition of 0.1%, 0.2%, and 0.3% volume fraction of fibers increases the fexural toughness by 44%, 271% and 387%, respectively. Silica fume increases the flexural toughness by 48% and 79% in the case of plain and fibrous concretes, respectively.

Potrzebowski[14] (1983) researched on the splitting test applied to steel fiber reinforced concrete. He tested on cube specimen cut from flexural test prisms,which were themselves obtained from slabs. The results show that the splitting tensile strength is strongly influenced by the number of fibers intersecting the failure plane and their orientation. Specimens subjected to the loads perpendicular to the plane of vibration are shown to give consistent results where as specimens loaded parallel to the plane of vibration gave low results.

Bhanja and Sengupta[15] (2003) worked on modified water cement ratio law for silica fume concrete. They reported modified relationships have been proposed to evaluate the strength of silica fume concrete. An extensive experiment was carried out to determine the isolated effect of silica fume on concrete and analysing the 28 day strength results of 32 concrete mixes performed over a wide range of water-binder ratios and silica fume replacement percentages, simplified models serve as useful guides for proportioning concrete mixes incorporating silica fume.

Bhanja and Sengupta[16] (2005) worked on Influence of silica fume on the tensile strength of concrete. Extensive experimentation was carried out over water–binder ratios ranging from 0.26 to 0.42 and silica fume–binder ratios from 0.0 to 0.3. For all the mixes, compressive, flexural and split tensile strengths were determined at 28 days. The compressive, as well as the tensile, strengths increased with silica fume incorporation, and the results indicate that the optimum replacement percentage is not a constant one but depends on the water–cementitious material (w/cm) ratio of the mix. Compared with split tensile strengths, flexural strengths have exhibited greater improvements. Based on the test results, relationships between the 28-day flexural and split tensile strengths with the compressive strength of silica fume concrete have been developed using statistical methods.

Zain, Safiuddin and Mahmud[17] (2000) worked on Development of high performance concrete using silica fume at relatively high water-binder ratios. For this purpose, water-binder ratios of 0.45 and 0.50 were considered. Test specimens were air and water cured and exposed to a medium temperature range of 20°C to 50°C. The compressive strength, modulus of elasticity and initial surface absorption (ISA) of hardened concrete were determined in the laboratory. Test results indicated that concrete under water curing offers the best results. The highest level of compressive strength and modulus of elasticity and the lowest level of ISA were produced by SF concrete under water curing and at temperature of 35°C. Data collected also revealed that, under controlled curing conditions, it is possible to produce HPC at relatively high water-binder ratios.

Bozkurt and Yagicioglu[18] (2010) studied on strength and capillary water absorption of light weight concrete under different curing conditions. Here they studied to investigate the influence of addition of pozzolanic materials and curing regimes on the mechanical properties and the capillary water absorption characteristics of lightweight concrete. They prepared specimens with volcanical pumice containing only Portland cement and 20% flyash and 10% silica fume as a replacement of cement. Specimens were cured for 3, 7, 28 days. Compressive, tensile, ultrasonic pulse velocity test were carried out. Capillary absorption coefficient were determined. Greater compressive, tensile strength and low capillary coefficient obtained in silica fume specimens.

Safiuddin and Hearn[19] (2005) worked on Comparison of ASTM saturation techniques for measuring the permeable porosity of concrete. There permeable porosity of two ordinary concretes has been determined by three ASTM saturation techniques, namely cold-water saturation (CWS), boiling-water saturation (BWS) and vacuum saturation (VAS). The concretes were prepared with the water–cement ratios of 0.50 and 0.60, and tested at ages of 7 and 28 days. Based on the test results of permeable porosity, the efficiency of the saturation techniques has been compared. In addition, the compressive strength of concretes was determined to justify the results of permeable porosity. The slump test was also performed to observe the workability. The overall experimental results reveal that vacuum saturation technique is more efficient than cold-water or boiling-water saturation and therefore this technique should be recommended for measuring the permeable porosity of concrete.

2.3. Critical observation from the literature:

- Not properly defined the use of RHA and GGBS.
- it was observed that not much work has been proceeded to find the optimum use of silica fume to produce good strength and durable concrete.
- The maximum percentage of synthetic fiber to be used in concrete along with silica fume to get good outcome..
- The effect of silica fumes with fiber on capillary and porosity of concrete.

2.4. Scope and Objective of present work:

The objective of the present work is to develope concrete with good strength, less porous, less capillatrity so that durablility will be reached. For this purpose it requires the use of different pozzolanic materials like rice husk ash, ground granulated blast furnace slag, silica fume along with fiber. So the experimental programme to be undertaken;

- To determine the mix proportion with rice husk ash, ground granulated blast furnace slag and silica fume with fiber to achieve the desire needs.
- To determine the water/ binder ratio, so that design mix having proper workability and strength.
- To investigate different basic properties of concrete such as compressive strength, splitting tensile strength, flexural strength etc and comparing the results of different proportioning.
- Determination of porosity and capillary of different proportioned concrete.

CHAPTER- 3

MATERIALS & PROPERTIES

3.1. GROUND GRANULATED BLAST FURNACE SLAG:

Ground Granulated Blastfurnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumino silicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportions varies.

The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The glass content of GGBS affects the hydraulic property, chemical composition determines the alkalinity of the slag and the structure of glass. The compressive strength of concrete varies with the fineness of GGBS.

Ground granulated blast furnace slag now a days mostly used in India. Recently for marine out fall work at Bandra, Mumbai. It has used to replace cement to about 70%. So it has become more popular now a day.

Table 3.1. Chemical composition (%) of GGBS:

SiO_2	39.18
Al_2O_3	10.18
Fe_2O_3	2.02
CaO	32.82
MgO	8.52

Na_2O	1.14
K_2O	0.30

Performance of Ground Granulated Blast furnace Slag in Concrete:

The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of water content is more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. Surface hydration of slag is slightly slower than that of cement. Reduction of bleeding is not significant with slag of 4000 cm^2/g fineness but significant when slag fineness of 6000 cm^2/g and above.

Advantages of using GGBS:

- Reduce heat of hydration
- Refinement of pore structures
- Reduce permeability to the external agencies
- Increase resistance to chemical attack.

Reaction Mechanism of Ground Granulated Blast furnace Slag:

Although GGBS is a hydraulically latent material, in presence of lime contributed from cement, a secondary reaction involving glass (Calcium Alumino Silicates) components sets in. As a consequence of this, cementitious compounds are formed. They are categorized as secondary C-S-H gel. The interaction of GGBS and Cement in presence of water is described as below:

Product of hydration of OPC

$$\textbf{OPC}(C_3S/C_2S) + H_2O \longrightarrow \text{C-S-H} + CH$$

Product of hydration of GGBS

$$\textbf{GGBS}(C_2AS/C_2MS) + H_2O \longrightarrow \text{C-S-H} + SiO_2$$

Reaction of pozzolanic material

$$SiO_2 + CH + H_2O \longrightarrow \text{C-S-H}$$

The generation of secondary gel results in formation of additional C-S-H, a principal binding material. This is the main attribute of GGBS, which contributes to the strength and durability of the structure. The diagrammatic representation of secondary gel formation is shown below.

3.2. RICE HUSK ASH:

Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When it is properly brunt it has high SiO_2 content and can be used as a concrete admixture. Rice husk ash exhibits high pozzolanic characteristics and contributes to high strength and high impermeability of concrete. Rice husk ash essential consists of amorphous or non crystalline silica with about 85- 90% cellular particle, 5% carbon and 2% K_2O. The specific surface of RHA is between 40000-100000 m^2/kg.

India produces about 122 million ton of paddy every day. Each ton of paddy produces about 40 kg of RHA. There is a good potential to make use of RHA as a valuable pozzolanic material to give almost the same properties as that of microsilica. In USA highly pozzolanic rice husk ash is patented under the trade name of Agrosilicaand is marketed.it is having superpozzolanic property when used in small quantity i.e. 10% by weight of cement and it greatly enhances the workability and impermeability of concrete.

Table 3.2. Chemical composition (%) of RHA:

SiO_2	85.88
K_2O	4.10
SO_3	1.24
CaO	1.12
Na_2O	1.15
MgO	0.46
Al_2O_3	0.47
Fe_2O_3	0.18
P_2O_5	0.34

Advantage of Rice husk ash:

Even with small dosages, for instance 10 percent by weight of cement rice husk ash can produce a very strong transition zone and very low permeability rating in concrete mixtures. In the cement having large size particles introduction of rice husk ash particles, which are micro porous blokes the channels of flow and internal pore of concrete improves. The major advantage of rice husk ash and silica fume is that they are very strong absorbents of sodium, potassium and other ions which are good conductors of electricity. A highly durable concrete with little or no corrosion in a sever environment can be obtained by improving the electrical resistivity of concrete by adding rice husk ash or silica fume.

3.3. SILICA FUME:

Silica fume also referred as microsilica or condensed silica fume is another material that is used as an artificial pozzolanic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. When quartz are subjected to 2000^0C reduction takes place and SiO vapours get into fuels. In the course of exit, oxidation takes place and the product is condensed in low temperature zones. In the course of exit, Silica fume rises as an oxidised vapour, oxidation takes place and the product is condensed in low temperature zones. When the silica is condensed, it attains non-crystalline state with ultra fine particle size. The super fine particles are collected through the filters. It cools, condenses and is collected in bags. It is further processed to remove impurities and to control particle size. Condensed silica fume is essential silicon dioxide (SiO_2) more than 90 percent in non crystalline form. Since it is an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000m^2/kg, as against 230 to 300 m^2/kg. The use of silica fume in conjunction with superplasticizer has been back bone of modern high performance concrete. High fineness, uniformity, high pozzolanic activity and compatibility with other ingredients are of primary importance in selection of mineral admixture. As Silica fume has the minimum fineness of 15,000 m^2/ kg, whereas the fumed Silica has the fineness of 190,000 m^2/g which is 6 to 7 times finer than Silica fume. Finer the particle of pozzolano, higher will be the modulus of elasticity, which enhances the durability characteristics of the High performance concrete.

Application of high performance concrete (HPC) has got momentum in various fields of construction globally in the near past. High performance concrete is being practised in the fields like construction of nuclear reactors, runways at airport, railway sleepers, cooling towers, silos, chimneys and all kinds of bridges. Considerable amount of development has been made in the field of High performance concrete and high strength concrete can be obtained using silica fume as a mineral admixture. Silica fume has been used for one of the fly over at Mumbai, India with concrete strength of 75 MPa.

Table 3.3. Chemical composition of silica fumes in %:

SiO_2	93
Al_2O_3	0.4
CaO	1.2
Fe_2O_3	0.2
MgO	1.2
Na_2O	0.1
K_2O	1.1
SO_3	0.3

Advantages of Silica fume:

- High strength concrete made with silica fume provides high abrasion/corrosion resistance.
- Silica fume influences the rheological properties of fresh concrete, the strength, porosity and durability of hardened mass.
- Silica fume concrete with low water content is highly resistant to penetration of chloride ions.
- The extreme fineness of silica fume allows it to fill or pack the microscopic voids between cement particle and especially in the voids at the surface of the aggregate particleswhere the cement particles cannot fully cover the surface of the aggregate and fill the available space.

- Silica fume can also be proportioned as a water reducer with the reduction in water cementitious material ratio, so it is hydrophilic in nature, thus super plasticizer demand for additional water can be minimised.
- Silica fume reduces bleeding segregation of fresh concrete significantly. This effect is caused due to high surface area.
- Highly durable concrete can be obtained by improving the electrical resistivity of concrete by the addition of silica fume.

Achieving adequate levels of durability in order to improve the performance and reduce the life cycle costs of concrete structures continues to be a serious problem for engineers. Benefits, in terms of high-strength concrete durability, of using additional binder materials. Some attempts were made to increase the early-age properties of the high-volume fly ash concrete by incorporating some activators and early-strength agents or small percentage (3% and 8.5%) of silica fume in the system. However, activators and early strength agents are generally alkaline substances, which may lead to alkali-silica reaction. At the same time, studies have shown that the use of silica fume did not significantly affect the early-age properties of the high-volume fly ash high-strength concrete (HFAC). The results of a study by researchers suggest that certain natural pozzolan-silica fume combinations can improve the compressive and splitting tensile strengths,workability, and elastic modulus of concretes, more than natural pozzolana or silicafume alone. Jianyong and Pei concluded that blending S and SF synergizes the advantages of these two admixtures so that the compressive strength, split tensile strength and rupture strength are improved while the fresh concrete mixture keeps a good workability.

Pozzolanic Action:

Silica fume is much more reactive than any other natural pozzolana. The reactivity of a pozzolana can be quantified by measuring the amount of $Ca(OH)_2$ in the cement paste.15 percentage of silica fume reduces the $Ca(OH)_2$ of cement sample from 24% to 90% at 90 days and from 25% to 11% in 180 days. The effect of silica fume can be explained by two mechanism i.e pozzolanic reaction and micro filler effect. The first product is calcium-silicate-hydrate (C-S-H) gel, that is cementitious and binds the aggregate together in concrete and $Ca(OH)_2$ The C-S-H formed by the reaction between microsilica and the product $Ca(OH)_2$ which comprises 25% of volume of hydration product. Silica fume reacts with calcium hydroxide to produce more aggregate binding C-S-H gel. Simultaneously reducing

$Ca(OH)_2$. The net result is increase in strength and durability.the second mechanism is through the micro filler effect. The extreme fineness of silica fumeallows it to fill or pack the microscopic voids.

3.4. SUPERPLASTICIZER:

There are two types of admixtures i.e Mineral admixtures and Chemical admixtures.

1) Mineral admixtures:

- Silica fume
- Ground granulated blast furnace slag
- Rice husk ash
- Fly ash

2) Chemical admixture:

- Accelerating admixture
- Retarding admixture
- Water-reducing admixture
- Air entering admixture
- Super- plasticizing admixture

Super plasticizing admixture:

A substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture (HRWRA) is also reffered as Superplasticizer, which is capable of reducing water content by about 20 to 40 percent has been developed. These can be added to concrete mix having a low-to-normal slump and water cement ratio to produce high slump flowing concrete. The effect of superplasticizers lasts only for 30to 60 minutes, depending on composition and dosage and is followed by rapid loss in workability.

One of the important factors that govern the issue water–cement ratio during the manufacture of concrete, lower the water-cement ratio lower will be the capillary pores and hence lower permeability and enhanced durability.

Although Superplasticizer are essential to produce a truly high performance concrete (HPC) characterised by low water-cement ratio and workability level without high cement content. Concrete are being produced with w/c ratio of as low as 0.25 or even 0.20 enabled the production of highly durable high performance concrete. The workability also increases with an increase in the maximum size of aggregate. But smaller size aggregate provides larger surface area for bonding with the mortar matrix, which increases the compressive strength. For concrete with higher w/c ratio use of larger size aggregate is beneficial.

High range superplasticizer was used in all the concrete mixes to achieve good workability. Superplasticizers are added to reduce the water requirement by 15 to 20% without affecting the workability leading to a high strength and dense concrete. To achieve the uniform workability, the admixture dosage was adjusted without changing the unit water content. This ensured the identical W/C ratio for a particular cementitious content and the effect of pozzolanic material replacement can directly be studied on the various properties of concrete.

Advantage of water reducing admixture:

- By the addition of admixture with the reduction in water-cement ratio, a concrete having the same workability and greater compressive strength can be obtained.
- By adding of the admixture with no decrease in water cement-ratio a concrete having same compressive strength but greater workability can be obtained.
- With the addition of admixture, a concrete with same workability and compressive strength can be obtained at lower cement content.

3.5. CEMENT:

Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. There are different types of cement, out of that I have used two types i.e,

- Ordinary Portland cement
- Portland slag cement

Ordinary port land cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction. It is of three type, 33 grade, 43 grade, 53 grade. One of the important benefit is the faster rate of development of strength.

Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag in suitable proportion and grinding the mixture to get a thorough and intimate mixture between the constituents. This type of cement can be used for all purposes just like OPC. It has lower heat of evolution and is more durable and can be used in mass concrete production.

3.6. AGGREGATE:

Aggregate properties greatly influence the behaviour of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

(I) Fine aggregate

(II) Coarse aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension.

According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted. In case of close reinforcement 10mm size also used.

3.7. FIBER:

An overview on Fibre:

In recent years, several studies have been conducted to investigate the flexural strengthening of reinforced concrete (RC) members with fiber reinforced composite fabrics. Recently, the use of high strength fiber-reinforced polymer (FRP) materials has gained acceptance as structural reinforcement for concrete.

In this composite material, short discrete fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of same cost. Due to this benefit, the use of FRC has steadily increased during last two decades and its current field of application includes airport and highway pavements, earthquake resistant and explosive resistant structures, mines and tunnel linings, bridge deck overlays, hydraulic structures, rock slope stabilization. Extensive research work on FRC has established that the addition of various types of fibers such as steel, glass, synthetic and carbon, in plain concrete improves strength, toughness, ductility, and post cracking resistance etc. The major advantages of fiber reinforced concrete are resistance to microcraking, impact resistance, resistance to fatigue, reduced permeability, improved strength in shear, tension, flexure and compression.

The character and performance of FRC changes with varying concrete binder formulation as well as the fiber material type, fiber geometry, fiber distribution, fiber orientation and fiber concentration.

Fiber materials:

According to terminology adopted by the American Concrete Institute (ACI) Committee 544, Fiber Reinforced Concrete, there are four categories of FRC based on fiber material type. These are Steel Fiber Reinforced Concrete, Glass Fiber Reinforced Concrete, Sinthetic Fiber Reinforced Concrete, including carbon fibers; and Natural Fiber Reinforced Concrete.

Fiber geometry:

Individual fibers are produced in an almost limitless variety of geometric forms including,

Prismatic: rounded or polygon cross-section with smooth surface or deformed throughout or only at the ends.

Irregular cross-section: cross-section varies along the length of the fiber.

Collated: multifilament (alternatively termed branching or fibrillated) or monofilament networks (or bundles) that are usually designed to separate during FRC production (mixing).

Equivalent diameter:

For fibers that are not circular and prismatic in cross-section, it is useful to determine what would be the diameter of an individual fiber if its actual cross-section were formed as a prismatic circular cross- section. The equivalent diameter of a fiber is the diameter of the circle having the same area as that of the average cross-sectional area of an actual fiber.

Relatively small equivalent diameter fibers have correspondingly low flexural stiffness and thus have a certain ability to conform to the shape of the space they occupy in

the paste phase of the concrete mixture in between aggregate particles. Relatively large equivalent diameter fibers have greater flexural stiffness and will have a correspondingly greater effect
on consolidation of aggregates during the process of mixing and placement.

Fiber aspect ratio:

The fiber aspect ratio is a measure of the slenderness of individual fibers. It is computed as fiber length divided by the equivalent fiber diameter for an individual fiber. Fibers for FRC
can have an aspect ratio varying from approximately 40 to 1000 but typically less than 300. This parameter is also a measure of fiber stiffness and will affect mixing and placing.

Fiber denier:

Principally when discussing about Synthetic fiber reinforced concrete, the term fiber denier is often used. This is terminology that evolved from the textiles industry. The denier of a fiber is defined as the weight, in grams, of 9000 metres of fiber.

Fiber content:

The concentration of fiber within a given unit volume of fiber reinforced concrete ranges from high to low relative to the total volume of concrete produced. It is useful to classify FRC on the basis of fiber concentration (volume percentage) as this one factor is seen to significantly affect mixing, placing, and hardened concrete performance, as much as any other single factor. Volume percentage may be considered high if in the range 3 to 12%, moderate if in the range 1 to 3%, and low if in the range 0.1 to 1.0%, based on the total volume of the concrete produced. The different ranges of fibers that can be used are given below in the fiber. The synthetic fiber is ranging from 0.1% to 2% used by volume percent of matrix.

Fiber count and specific surface:

Fiber count *(FC)* and fiber specific surface *(FSS)* are the number of fibers in a unit volume of FRC and the surface area of fiber in a unit volume of FRC, respectively. Consider the mass of an FRC composite based on volume basis. The total volume of fiber in any given unit of volume of composite, i.e. the volume fraction (or percentage if multiplied by 100), may consist of only one single (large) fiber or it may be any number of smaller individual fibers.

Recently developed a new type of fiber manufactured by Reliance company come in to picture i.e, Recron Fiber. Which is a synthetic fiber.

3.7.1. Recron Fiber:

Recron Fibrefill is India's only hollow Fibre specially designed for filling and insulation purpose. Made with technology from DuPont, USA, Recron Fibrefill adheres to world-class quality standards to provide maximum comfort, durability, and ease-of-use in a wide variety of applications like sleep products, garments and furniture. Reliance Industry Limited (RIL) has launched Recron 3s fibres with the objective of improving the quality of plaster and concrete.

Application of RECRON 3s fibre reinforced concrete used in construction. The thinner and stronger elements spread across entire section, when used in low dosage arrests cracking. RECRON 3s prevents the shrinkage cracks developed during curing making the structure/plaster/component inherently stronger.

Further when the loads imposed on concrete approach that for failure, cracks will propagate, sometimes rapidly. Addition of RECRON 3s in concrete and plaster prevents/arrests cracking caused by volume change (expansion & contraction).

A cement structure free from such micro cracks prevents water or moisture from entering and migrating throughout the concrete. This in turn helps prevent the corrosion of steel used for primary reinforcement in the structure. This in turn improves longevity of the structure.

The modulus of elasticity of RECRON 3s is high with respect to the modulus of elasticity of the concrete or mortar binder. The RECRON 3s fibres help increase flexural strength.RECRON 3s fibres are environmental friendly and non hazardous. They easily disperse and separate in the mix.

Only 0.2-0.4% by cement RECRON 3s is sufficient for getting the above advantages. Thus it not only pays for itself, but results in net gain with reduced labour cost & improved properties. So we can briefly summarize the advantages of Recron 3s fiber as,

- Control cracking
- Increase flexibility
- Reduction in water permeability
- Reduction in rebound loss in concrete
- Safe and easy to use

This can be used in various aspects such as,

- PCC and RCC plastering
- Shortcrete and gunniting
- Slabs, footings, foundations, walls and tanks
- Pipes, prestressed beam etc
- Concrete blokes, railway sleepers, manhole cover and tiles etc
- Roads and pavements
- Bridges and dams

Table 3.4. Specification of Recron:

Denier	1.5d
Cut length	6mm,12mm,24mm
Tensile strength	About 6000 kg/cm^2
Melting point	➢ 250^o C
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	good

CHAPTER- 4

EXPERIMENTAL PROGRAMMES

4.1. OUTLINE OF PRESENT WORK:

Rice husk ash is a product confirming to engineering requirements in terms of physical and chemical properties. So in our present study we are going to put our great diligence in study of RHA which can be made as a partial cement replacing material simultaneously achieving required strength testing on mortar cubes. GGBS is a non-metallic product essentially consists of silicates and alumino silicates of calcium and other bases. The four major factors, which influence the hydraulic activity of slag, are glass content, chemical composition, mineralogical composition and fineness. The granulated material when further ground to less then 45 micron will have specific surface of about 400-600 m^2/kg (Blaine). But here in our present study we have delved into the use of GGBS in different percentages in mortar testing, where we have used GGBS passing through 75 micron sieve. Here the specific surface of about275-550 m^2/kg. We are going to use of GGBS as partial replacement of cement because of its advantages like lower energy cost, higher abrasion resistance, lower hydration heat evolution, higher later strength development.

Synthetic fiber i.e Recron fiber is used in concrete for the production of fiber reinforced concrete. We are going to use Recron fiber in different percentage i.e, 0%, 0.1%, 0.2%, 0.3% to the weight of concrete and study the 7 days and 28 days compressive strength, splitting tensile and flexural strength of concrete to that of normal concrete with maintaining the water cement ratio in the range of 0.35-0.41. Then with different percentages of silica fume i.e, 10%, 20%, 30% fixing constant fiber percentage at 0.2% cubes, cylinders and prisms were casted and tested to analyse the change in compressive, splitting tensile and flexural strength. We used two types of cement for our study i.e Portland slag cement and ordinary Portland cement (53 grade). XRD test was being conducted to idealize the chemical composition RHA, GGBS, silica fume. Finally Porosity and Capillary absorption test was conducted on different specimens to analyse the affect of silica fume on concrete.

Different material used in this study are given below for the strength evaluation of concrete using different pozzolanic material , fiber and super plastisizer.

Cement:

For the experiment following two types cements were used,

(a) Portland Slag Cement

(b) Ordinary Portland cement (53 grade)

The chemical composition and different properties are shown below.

Fineness – 340 m^2/kg

Specific gravity- 2.96

Initial setting time - 120 min

Final setting time – 240 min

Table 4.1. Properties of Portland slag cement:

Specific gravity	2.96
Initial setting time (min)	125
Final setting time (min)	235

Table 4.2. Properties of Ordinary Portland cement:

Specific gravity	3.1
Initial setting time (min)	90
Final setting time (min)	190

Fine aggregate:

In this study it was used the sand of Zone-II, known from the sieve analysis using different sieve sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ) adopting IS 383:1963.

Table 4.3. Properties of fine aggregate:

Properties	Results Obtained
Specific Gravity	2.65
Water absorption	0.6%
Fineness Modulus	2.47

Coarse aggregate:

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10mm size and 40% 20mm.

Table 4.4. Properties of coarse aggregate:

Specific gravity	2.67
Water absorption	0.4%
Fineness modulus	4.01

Fiber:

In this project work it was used Recron fiber. It is a type of synthetic fiber. In different weight fraction (0.0%, 0.1%, 0.2%, 0.3%) to concrete it was used.

Ground granulated blast furnace slag (GGBS):

As pozzolanic activity greatly depends on fineness, so GGBS passing through 75 micron whose fineness of order of 275-550 m^2/kg was used. Specific gravity test was conducted using Le-Chatelier apparatus and found to be 2.77. X-Ray diffraction test was conducted shown below in figure no. 4.1.

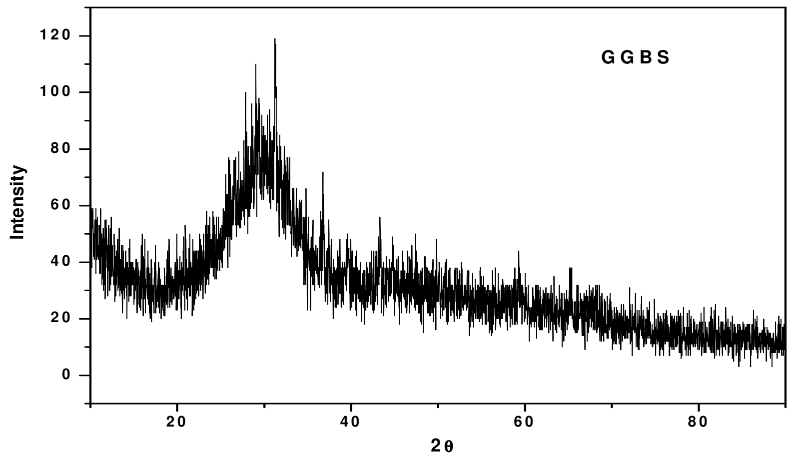


Fig. 4.1 X-Ray Diffraction test of GGBS

Rice husk ash:

In this study we have used two types of Rice husk Ash. First type which was low burned having greater percentages of carbon (which is having negative impact on strength development), so looking black and second type is looking white because it was being burnt in higer temperature. Here in second type of RHA the percentage of carbon is low. The specific gravity test was carried out using Le- Chatelier apparatus and found to be 2.21 for RHA– I and 2.20 for RHA-II. X-Ray diffraction test was carried out shown below in fig no. 4. 2 and fig no. 4.3.

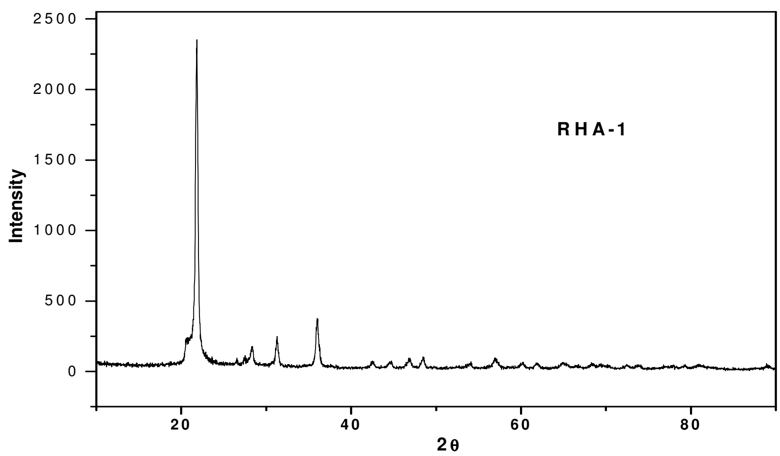


Fig.4.2 X-Ray Diffraction test of RHA-I

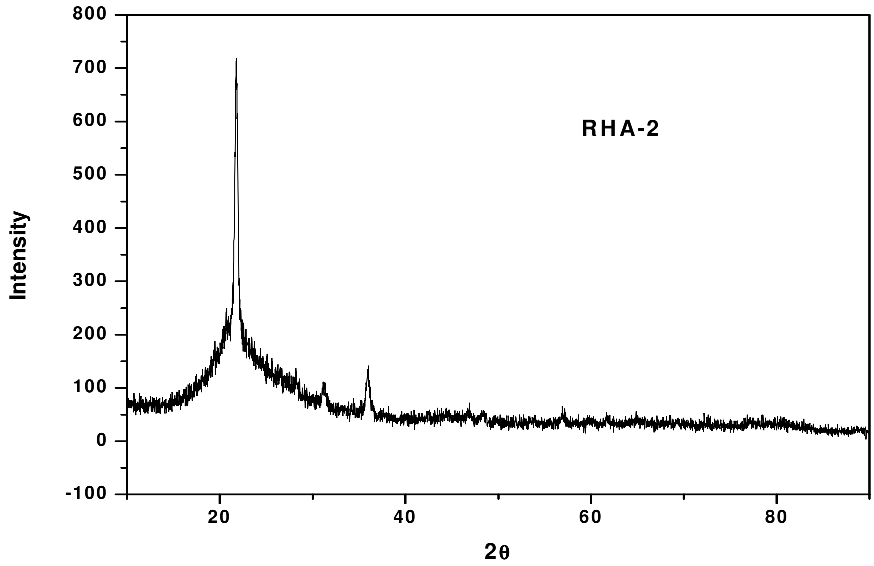
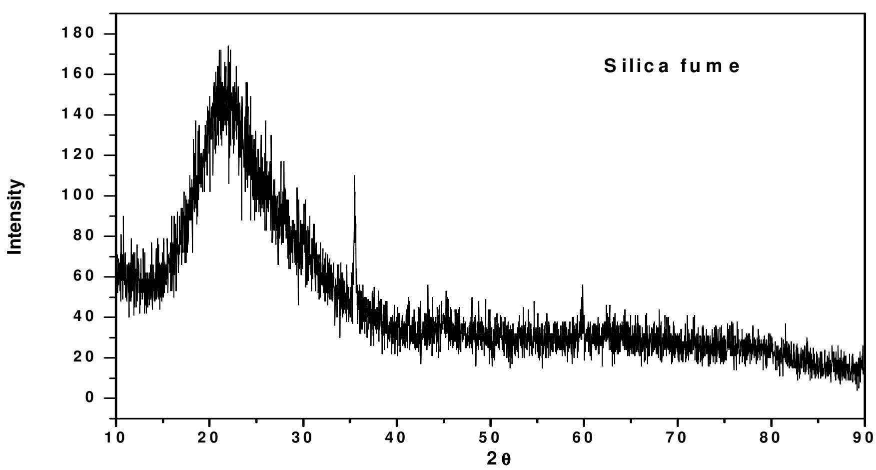


Fig. 4.3 X-Ray Diffraction test of RHA-II

Silica fume:

Silica fume is used in different percentage (0%, 10%, 20%, 30%) with the replacement of cement for its greater pozzolanic activity along with fiber. The specific gravity of silica fume was found out using Le-Chatelier apparatus and found to be Specific gravity- 2.36. X-Ray diffraction test was conducted shown below in figure no. 4.4.



. **Fig. 4.4 X-Ray Diffraction test of silica fume**

4.2. RESULTS AND DISCUSSION OF XRD TEST:

XRD was conducted on RHA-I, RHA-2, GGBSS and Silica fume, to idealize the different chemical composition of these pozzolanic material. Test was performed at an angle 45^o with 2θ equal to 90^o and different graphs are obtained, which were analysed using "X-pert High Score" software.

In case of GGBS from the graph it is inculcated that compound purely in amorphous form. Here we got the formation of $Mg_2Al_2O_4$ corresponding to no. 74-1133 and Mg_2SiO_4 with no.74-1680. From the XRD graphs of RHA-I and RHA-II obtained from X-pert High Score software, it was visualised that RHA-I (black type) somehow is in crystalline form as compared to RHA-II (white type). But in both the form of rice husk ash we found crystabalite low temperature silica type with no. 76-0939 as to that of software. The graph shows silica fume also is in amorphous state with having compound SiO_2 and CaO with nos. 03-0865 and 80-2146 respectively in the software used.

4.3. EFFECT OF GGBS AND RHA ON PROPERTIES OF CEMENT

To know the properties of GGBS and RHA on mortar we performed different tests

- Consistency test
- Compressive strength

The amount of water required to produce a standard cement paste to resist a specified pressure is known as normal or standard consistency. In other word it is the limit of water required at which the cement paste resist the penetration of standard plunger (1 mm diameter) under a standard loading up to a distance of 5-7 mm from the base of Vicat apparatus. The consistency of cement depends on its type and fineness. More water is required in cement with higher fineness value. The water quantity was calculated by [(P/4) + 3] % of 800 gm. Consistency test was performed with both GGBS and rice husk ash of different percentage content. That is GGBS with 0, 10, 20, 30, 40 % and RHA with 0, 10, 20, 30 %. Then mortars of standard size were casted with different percentage of GGBS (0%, 10%, 20%, 30%, 40%) and RHA (0% and 20%) with the replacement of cement. Portland slag cement and sand of zone- II was used in this experiment. Then compression test was conducted of mortars in Compression testing machine.

4.3.1 TEST RESULT:

Table 4.5. Effect of GGBS in normal consistency of cement:

% of cement replaced by GGBS (%)	Consistency (%)
0	31.0
10	32.0
20	33.0
30	34.5
40	36.5

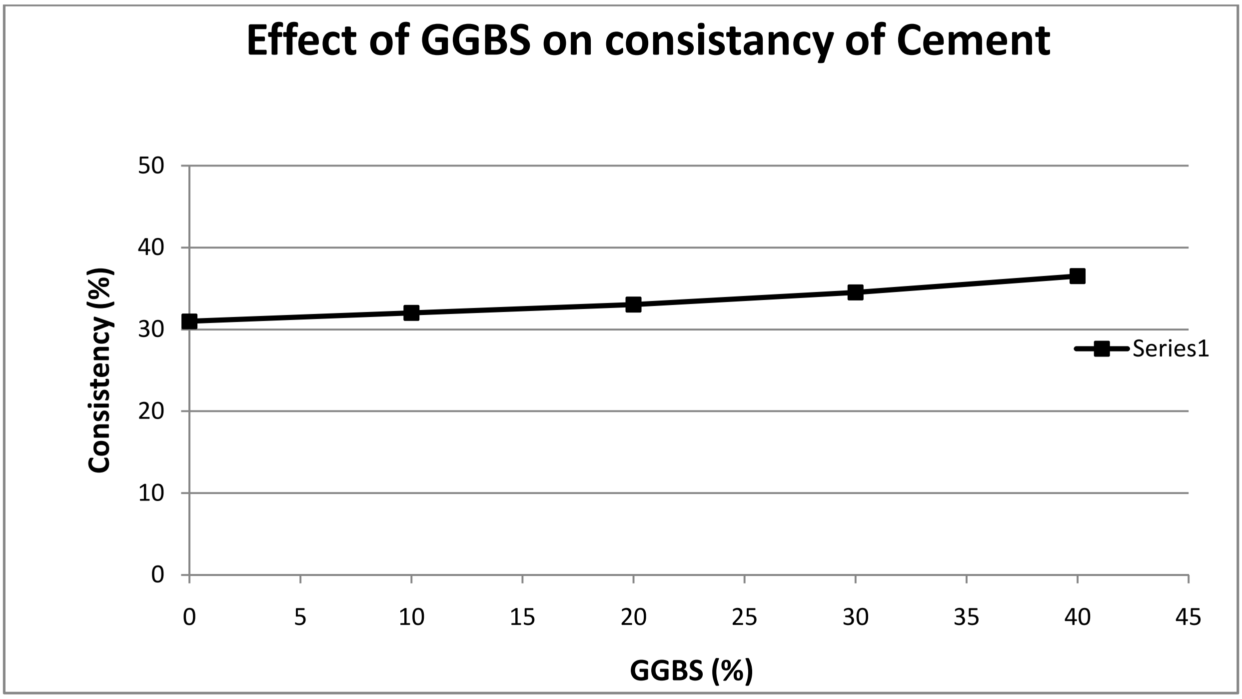


Fig. 4.5 Variation of Consistency of cement containing different % of GGBS

Table 4.6. Effect of GGBS on Compressive strength of cement:

% of GGBS with cement replacement	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
10	9.66	15.63
20	7.117	10.85
30	6.10	9.15
40	4.74	7.46

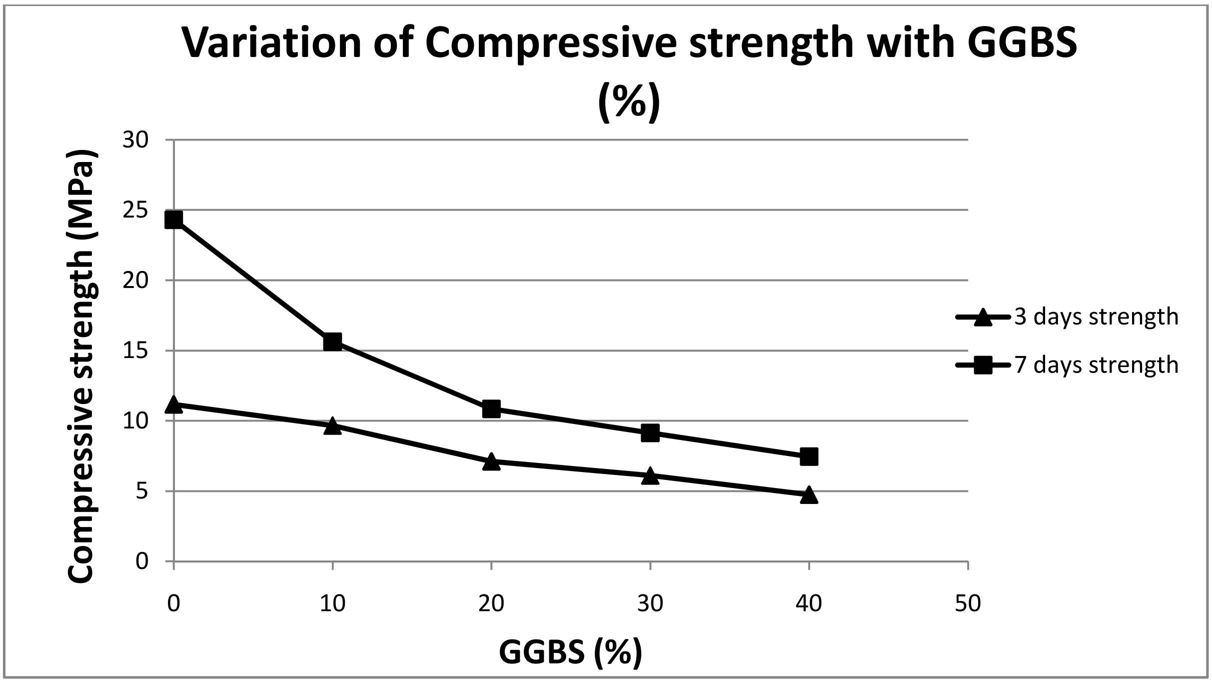


Fig. 4.6 . Variation of Compressive strength of mortar with different GGBS %

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Table 4.7. Effect of RHA on Normal Consistency of cement:

% of cement replaced by RHA	Consistency (%)
0	31.0
10	45.0
20	48.0
30	52.0

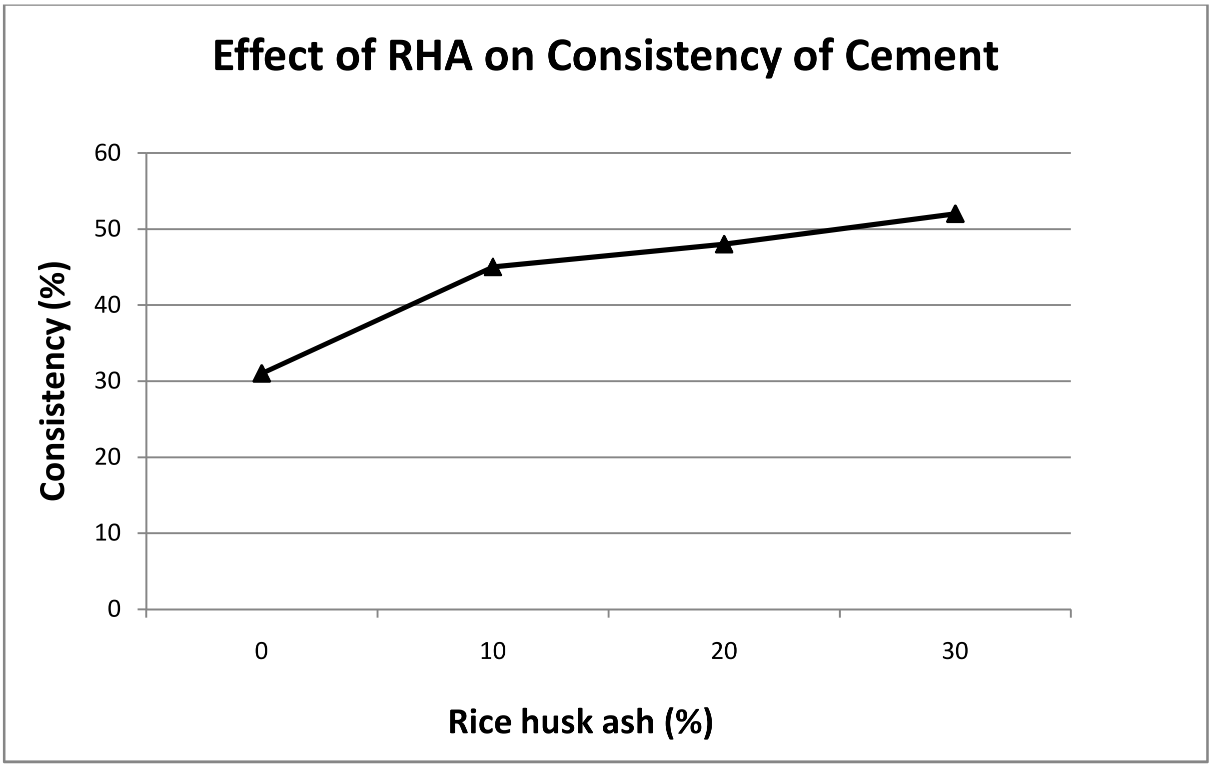

Fig. 4.7 Variation in Consistency of cement with different % of RHA

Table 4.8. Effect of RHA on Compressive strength of cement:

% of cement replaced by RHA	3 days strength (MPa)	7 days strength (MPa)
0	11.176	24.31
20% (RHA I)	2.23	4.74
20% (RHA II)	3.65	7.45

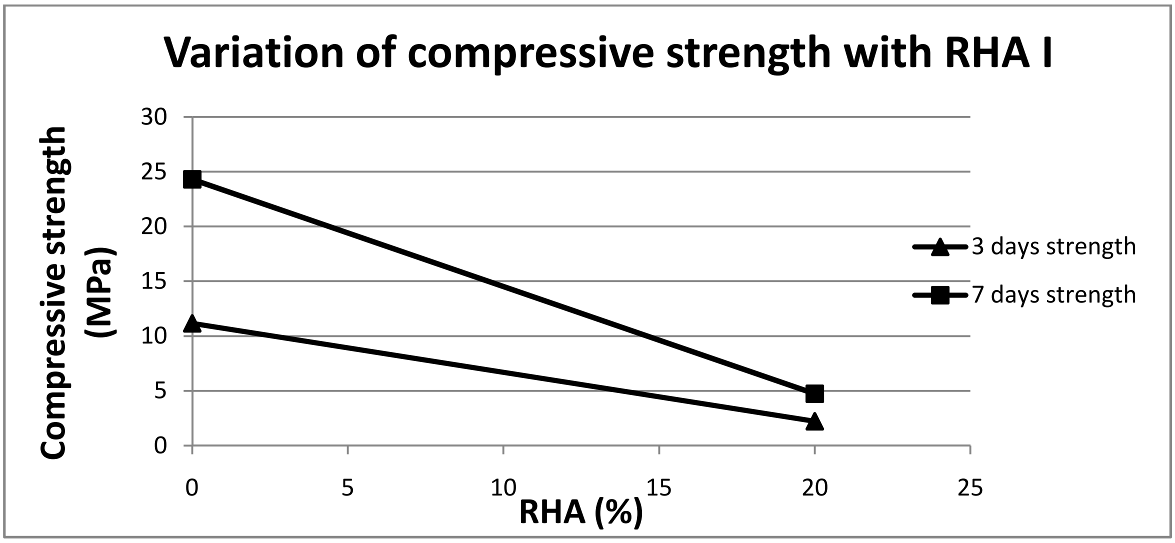

Fig. 4.8 Variation in Compressive strength of mortar with use of RHA I

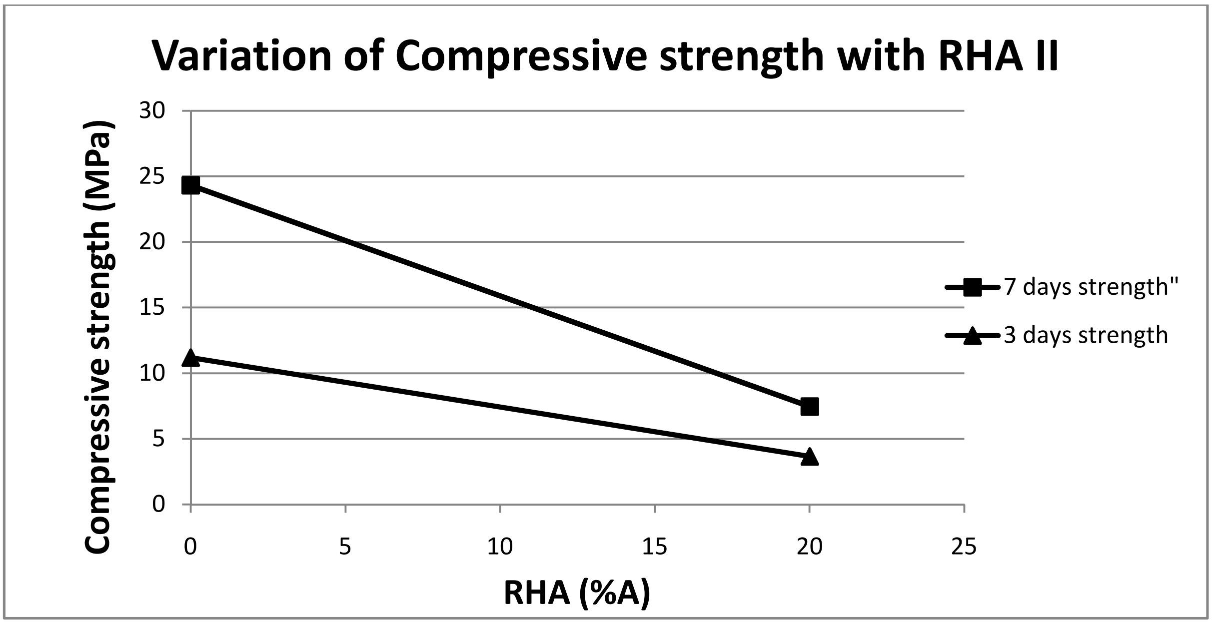

Fig. 4.9 Variation in Compressive strength of mortar with use of RHA II

4.3.2. DISCUSSION:

It is observed here that the consistency percentage is increasing as the percentage of GGBS increases as a cement replacement, but the change is not so abrupt. But found that as we go on increasing the percentage of Rice husk ash the consistency percentage increases rapidly.

The variation of compressive strength of mortar mix with different proportion of GGBS partial replacement of cement is shown in fig. It was observed that 3 days and 7 days compressive strength reduces about 13% and 35% that is from 11.176 MPa to 9.66 MPa and 24.31 to 15.63 respectively, as GGBS percentage increases from 0 to 10%. If percentage of GGBS was further increased the compressive strength reduces greatly. Finally when the GGBS percentage increased to 40% the strength reduces by about 60% and 70% in 3 days and 7 days respectively of its initial values. So it was concluded that the use of GGBS specially in Portland slag cement leading to adverse effect on strength of mortar. Also use of Rice husk ash as a partial replacement of cement is not giving satisfactory strength. Although RHA II (white type) is giving better strength as compared to that of RHA I, still it was not of to the mark. Though RHA I having higher carbon percentage, it is not suitable for using as a pozzolanic material leads to give very poor strength and RHA II which was burnt more than as compared to RHA I, so here the carbon percentage was less and looking white in colour.

4.4. MIX PROPORTIONING OF RECRON-FIBER REINFORCED CONCRETE:

To develop Recron fiber reinforced concret and to study the effect of silica fume keeping fiber percentage constant concrete specimen were casted. For this purpose it was used two types of cement i.e Portland slag cement and ordinary Portland cement (53 grade). Coarse aggregate of maximum size 20 mm size and sand of zone- II were used. In case of fiber reinforced concrete, Recron fiber in different percentages i.e 0, 0.1, 0.2, 0.3% to the weight of concrete was used. Then it was varied the percentages of silica fume i.e 10, 20, 30% keeping the percentage of fiber constant to study the effect of silica fume. It was maintained the slump in the range of 50-75mm for proper workability for the easy handling and placing in all cases. To maintain this admixture Sika was used keeping water cement ratio in the range of 0.35-0.41 (0.35, 0.37, 0.39, 0.41) and 0.41-0.45 (0.41, 0.42, 0.45) and super plasticizer rages from 0.6%-1.4% (0.6, 0.9, 1.2, 1.4%) and 1.4%-1.7% (1.4, 1.5, 1.7%) for ordinary fiber reinforced concrete and FRP with the addition of silica fume respectively. Aggregate binder ratio= 3.08, coarse aggregate to fine aggregate ratio= 2.34. In case OPC, mix was obtained with water cement ratio 0.38 and admixture at 0.8% for normal concrete mix. Then with different percentage of silica fume (10, 20, 30%) with constant 0.2% fiber content keeping water cement ratio (0.422, 0.44, 0.46) and admixture (1.4, 1.6, 1.7%).

All mixtures were mixed in a conventional rotary drum concrete mixer. The mixer was first loaded with the coarse aggregate and a portion of the mixing water, then sand, cement and the rest of water were added and mixed for 3 min. The fibers in the case of fibrous mixtures was randomly distributed. The admixture Sika was added to the mixing water and in case of (cement + silica fume) was added with cement simultaneously. Then concrete was casted, vibrated in vibrating machine and moulded to cubes, cylinders and prisms of sizes 150mm cubes, cylinder of height 300mm and diameter 150, prism of length 500 mm height and breadth of 100 mm each. All specimen were demoulded after 24 hour. Finally all the specimen were cured for 7 days and 28 days. compressive strength, splitting tensile strength and flexural strength were evaluated on cubes, cylinders, prisms respectively according to the Indian standard codes. i.e IS 456: 2000,IS 5816:1999, IS 561: 1959, IS 9399-1979 and IS 10262-1982.

Compressive Strength, $\boldsymbol{C = {}^{P}/_{A}}$

Where, P= load in Newton

A= area of cross section of cube in mm^2

Splitting tensile strength, $\boldsymbol{S = {}^{2P}/_{\Pi \times l \times d}}$

Where,P= load in Newton

l= length of cylinder in mm i.e 300mm

d= diameter of cylinder in mm i.e 150mm

Flexural strength, $\boldsymbol{F = Pl/b \times h^2}$

Where, P= load in Newton shown in dial gauge

l= length of rectangular prism in mm i.e 500 mm

b= breadth of rectangular prism i.e 100 mm

h= height of rectangular prism i.e 100 mm

Before using silica fume consistency test was conducted on silica fume with the replacement of different percentage of cement to analyse the water absorption. Then porosity and capillary absorption test were conducted on half cylinder to analyse the effect of silica fume on voids in different concrete mixes.

Firstly with Portland slag cement the effect of fiber and SF on strength of concrete are shown below then using OPC.

Fig. 4.10 Determination of compressive strength of cube

Fig. 4.11 Determination of splitting tensile strength of cylinder

Fig. 4.12 Determination of Flexural strength of prism

4.4.1 TEST RESULT:

Table 4.9. Effect of Recron fiber on Compressive strength using slag cement:

Fiber content (%)	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
0.0	29.036	37.77
0.1	24.63	27.4067
0.2	26.43	32.148
0.3	17.2	25.48

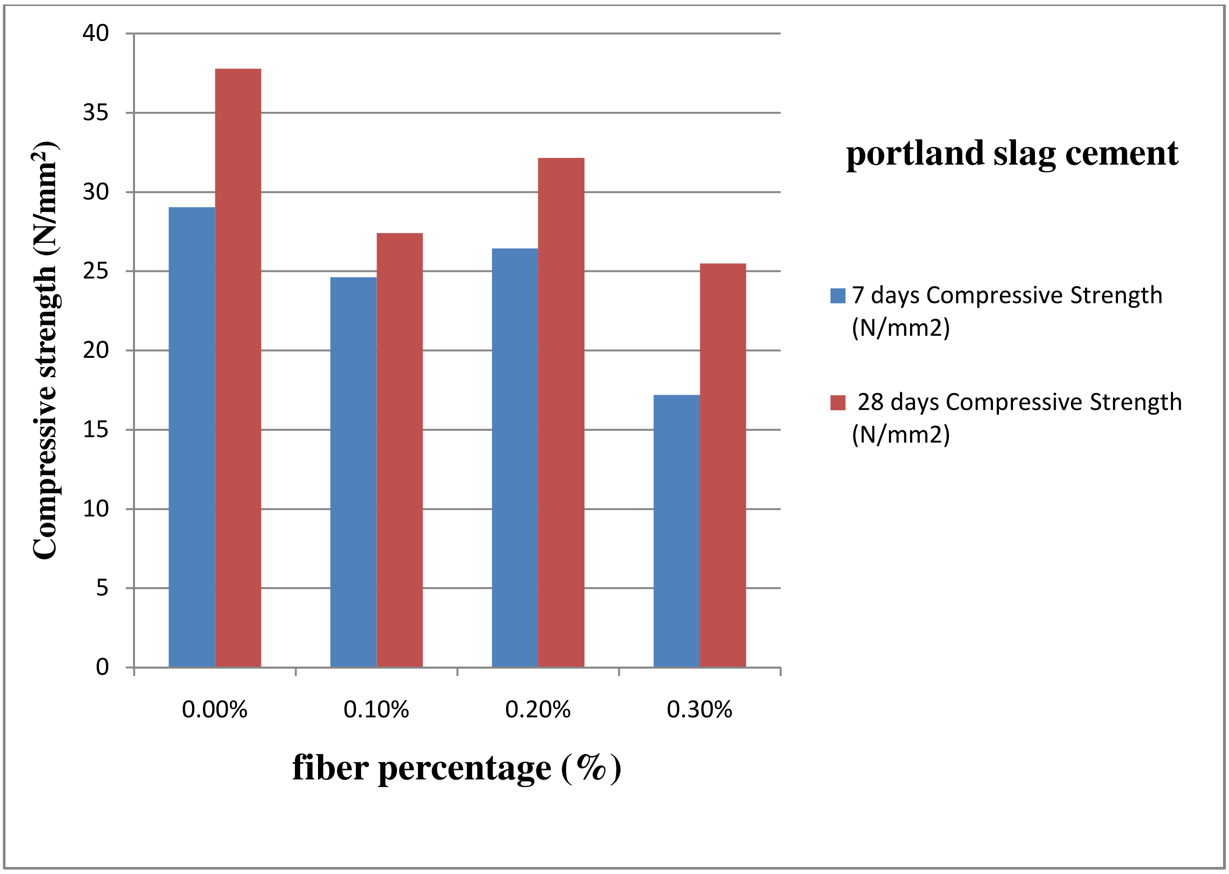

Fig. 4.13 Effect of Recron fiber on compressive strength

Table 4.10. Effect of recron fiber on Splitting Tensile Strength using slag cement:

Fiber content (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0	**2.523**	**2.873**
0.1	**2.12**	**2.452**
0.2	**2.569**	**3.018**
0.3	**1.533**	**2.280**

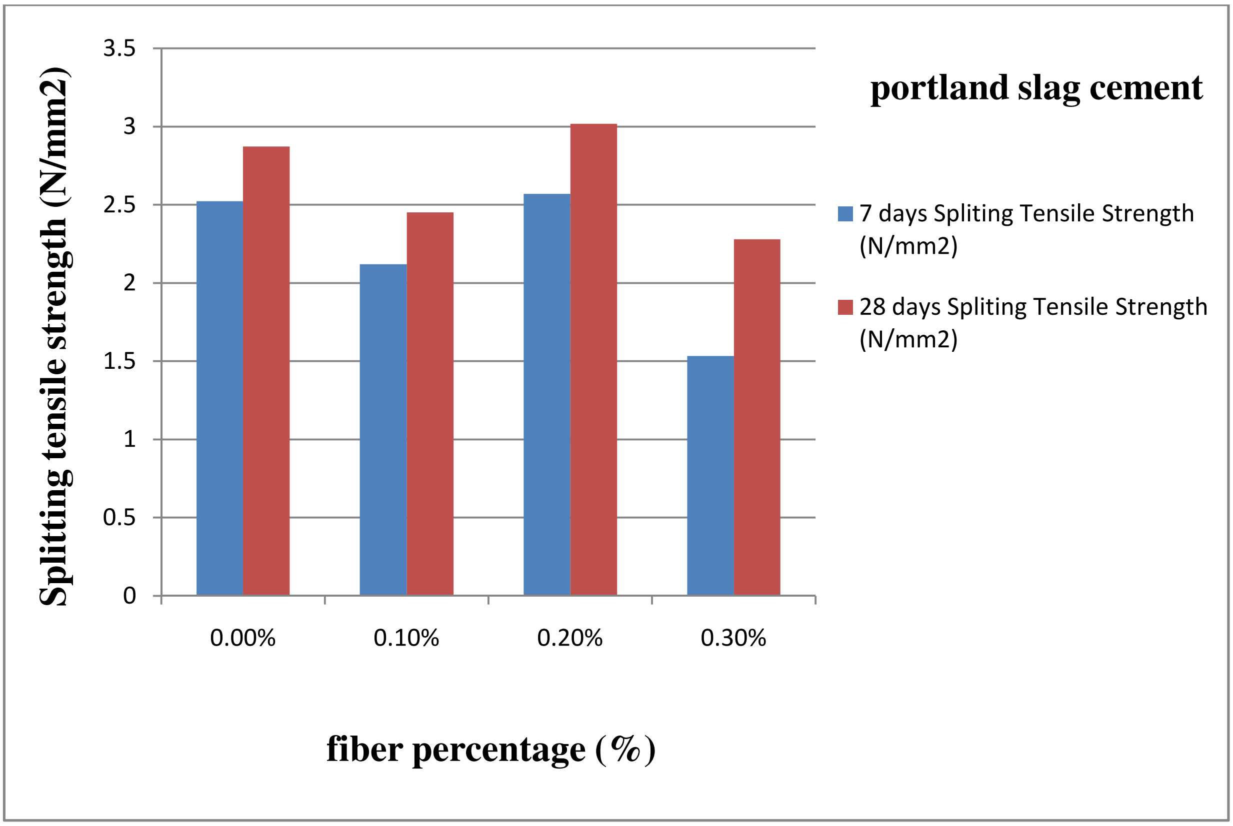

Fig. 4.14 Effect of Recron fiber on splitting tensile strength

Table 4.11. Effect of recron fiber on Flexural Strength using slag cement:

Fiber content (%)	7 days flexural strength (N/mm^2)	28 days flexural strength (N/mm^2)
0.0	5.750	7.75
0.1	5.875	6.33
0.2	6.560	8.04
0.3	4.501	6.04

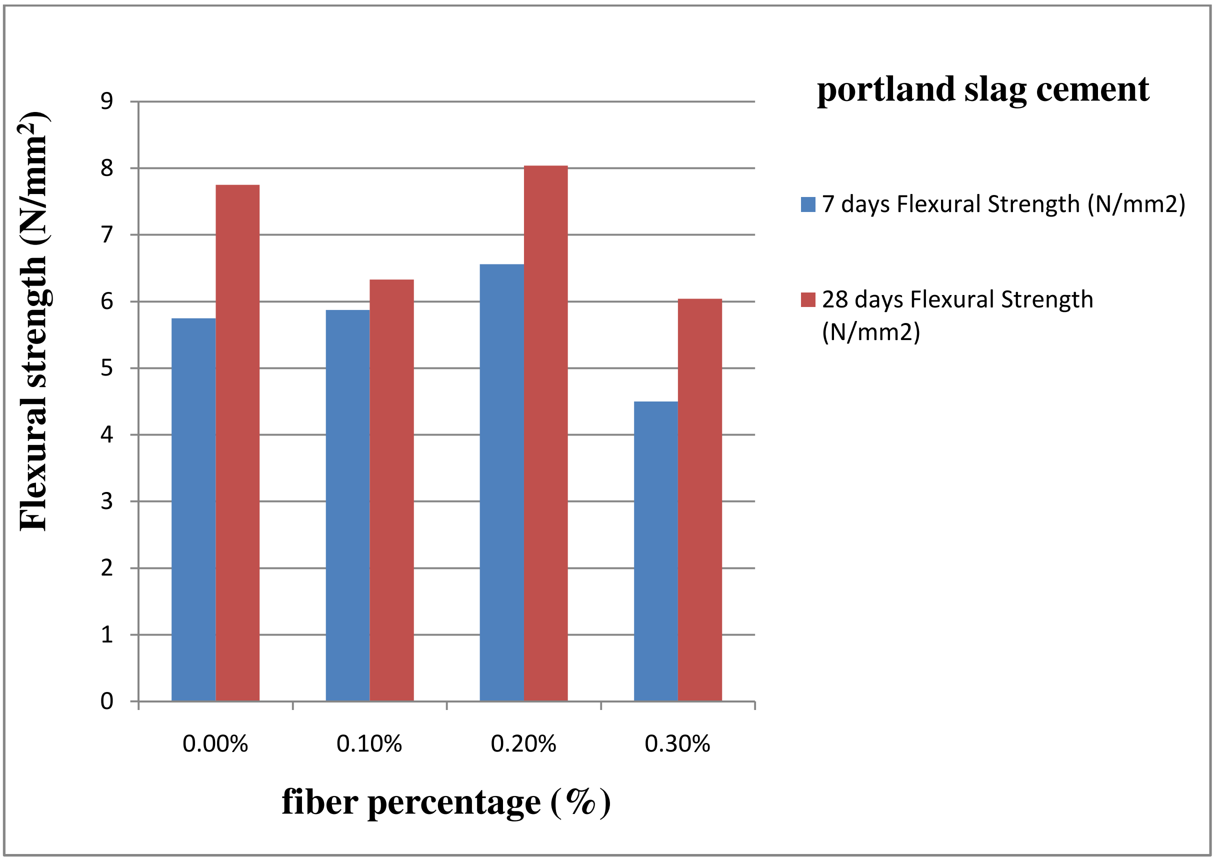

Fig. 4.15 Effect of Recron fiber on flexural strength

Table 4.12. Effect of silica fume on normal consistency of cement:

% of cement replaced by silica fume	Normal consistency (%)
0	31.0
10	38.0
20	41.5
30	45.0

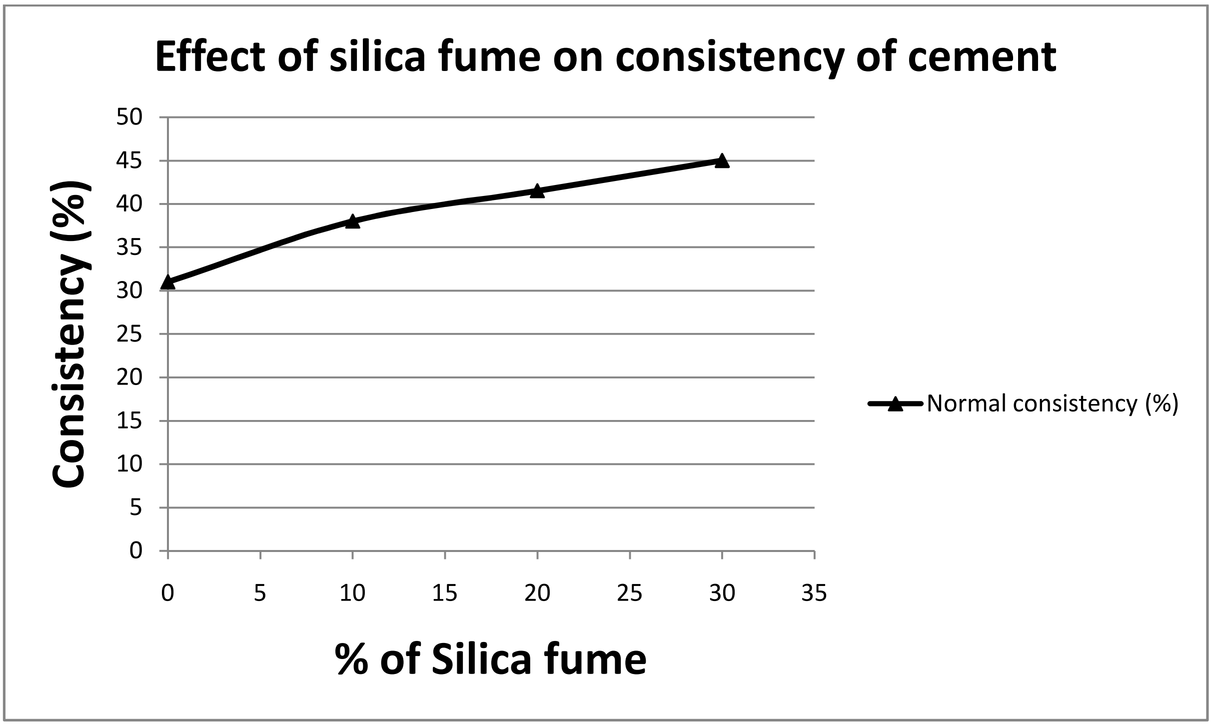

Fig. 4.16 Effect of silica fume on consistency of cement

Table 4.13. Effect of silica fume on Compressive strength with 0.2%fiber using slag cement:

Silica fume (%)	7 days Compressive strength (N/mm^2)	28 days Compressive strength (N/mm^2)
0.0	26.43	32.148
10.0	23.55	30.813
20.0	26.07	34.814
30.0	21.778	29.03

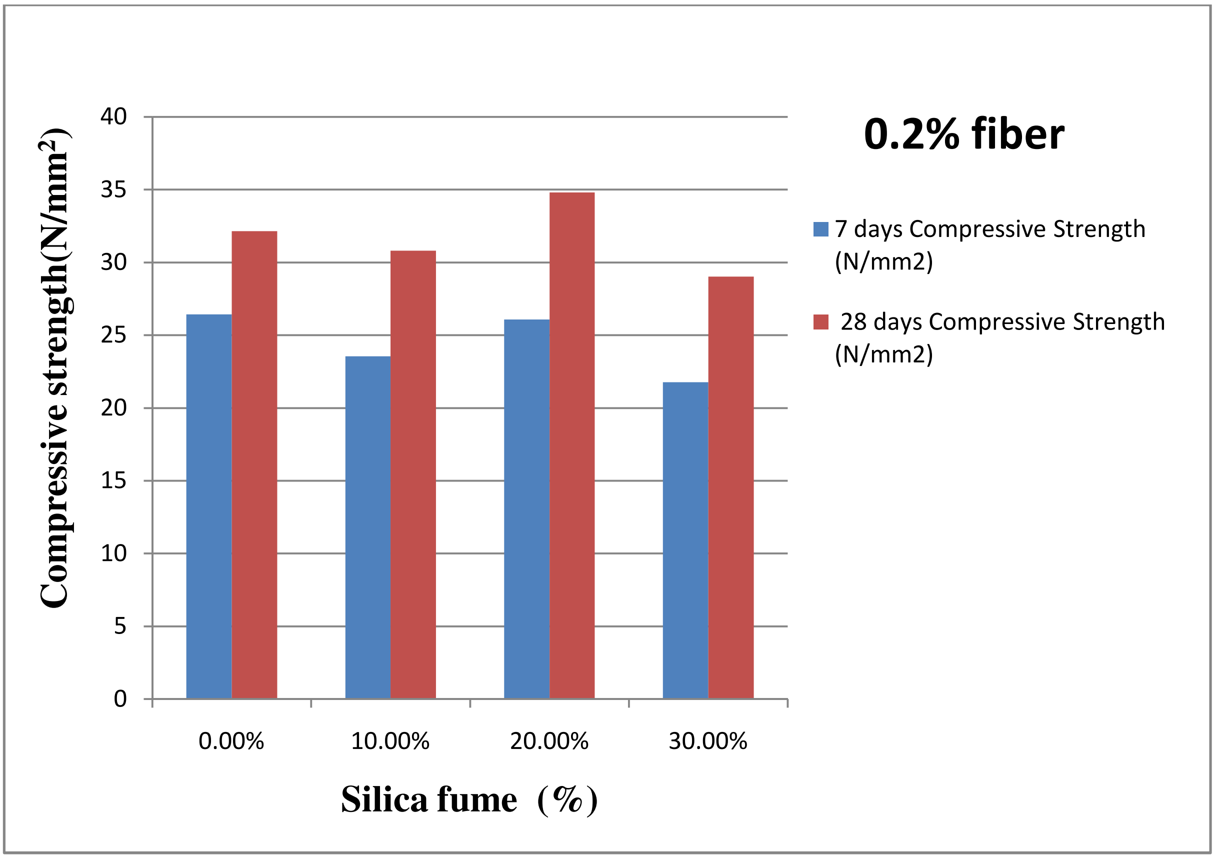

Fig. 4.17 Effect of silica fume on compressive strength at 0.2% fiber with slag cement

Table 4.14. Effect of silica fume on splitting tensile strength with 0.2%fiber using slag cement:

Silica fume (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0	**2.569**	**3.018**
10.0	**2.482**	**2.92**
20.0	**2.687**	**3.206**
30.0	**2.169**	**2.782**

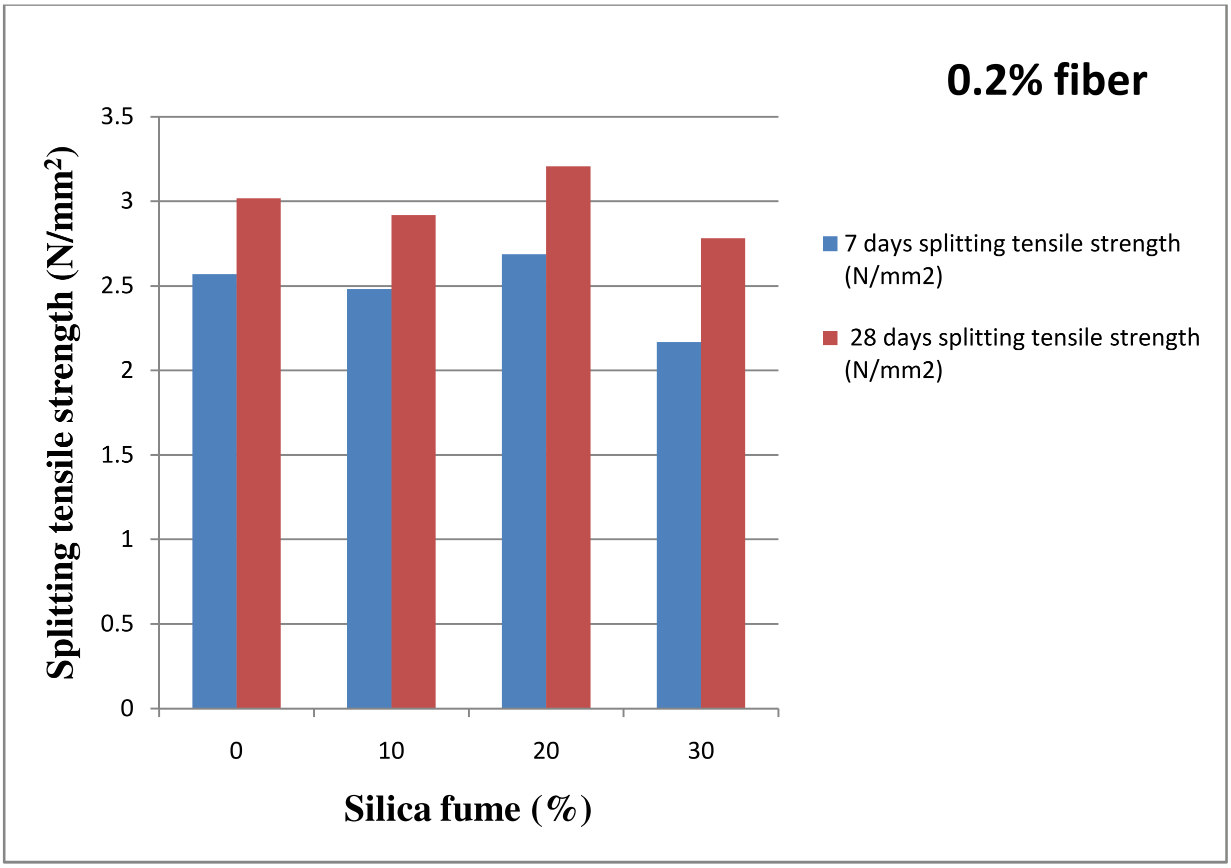

Fig. 4.18 Effect of silica fume on splitting tensile strength at 0.2% fiber with slag cement

Table 4.15. Effect of silica fume on flexural strength with 0.2%fiber using slag cement:

Silica fume (%)	7 days flexural strength (N/mm^2)	28 days flexural strength (N/mm^2)
0.0	6.56	8.04
10.0	6.50	8.00
20.0	6.625	8.458
30.0	6.04	7.875

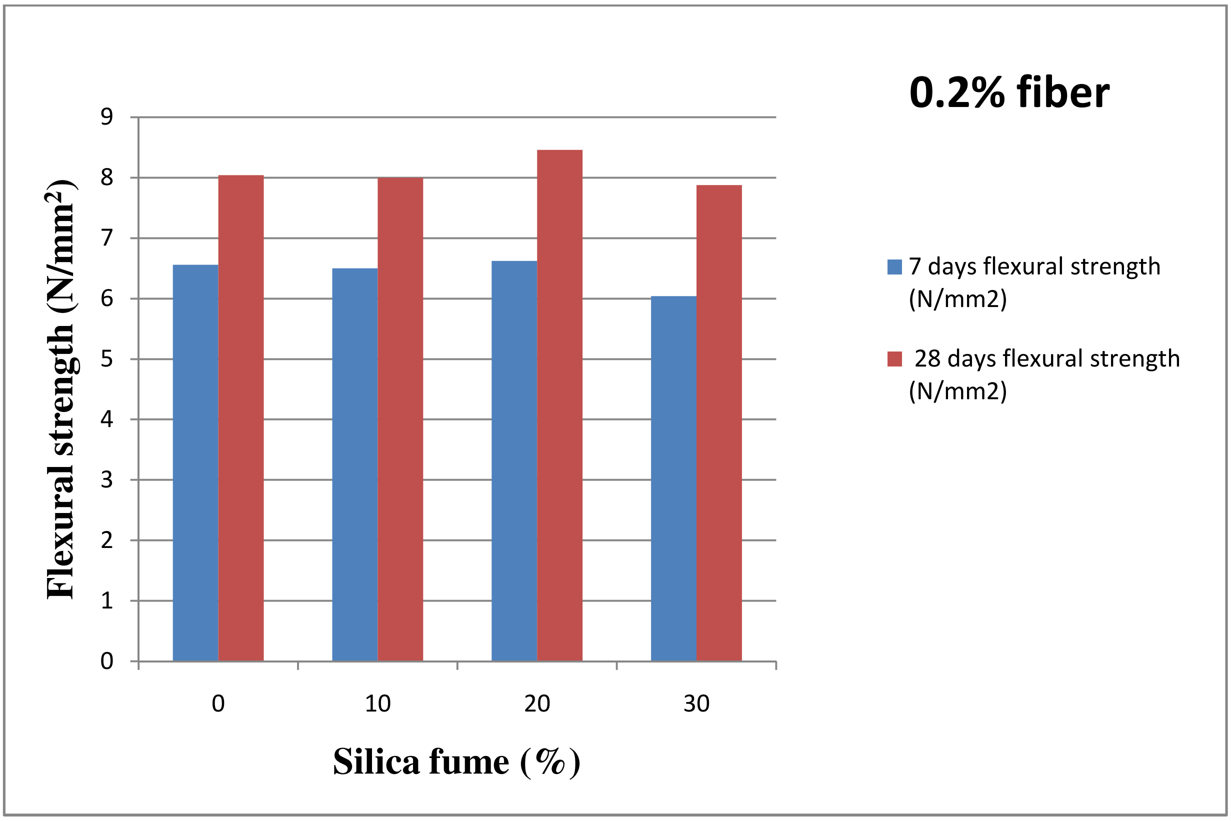

Fig. 4.19 Effect of silica fume on flexural strength at 0.2% fiber with slag cement

Effect of silica fume with constant fiber percentage (0.2%) using ordinary Portland cement is given below;

Table 4.16. Effect of silica fume on Compressive strength using OPC:

Silica fume (%)	7 days Compressive strength (N/mm^2)	28 days Compressive strength (N/mm^2)
0.0(0.2%fibre)	**29.00**	**35.33**
10.0(0.2%fibre)	**29.50**	**36.00**
20.0(0.2%fibre)	**32.00**	**38.28**
30.0(0.2%fibre)	**34.50**	**42.32**

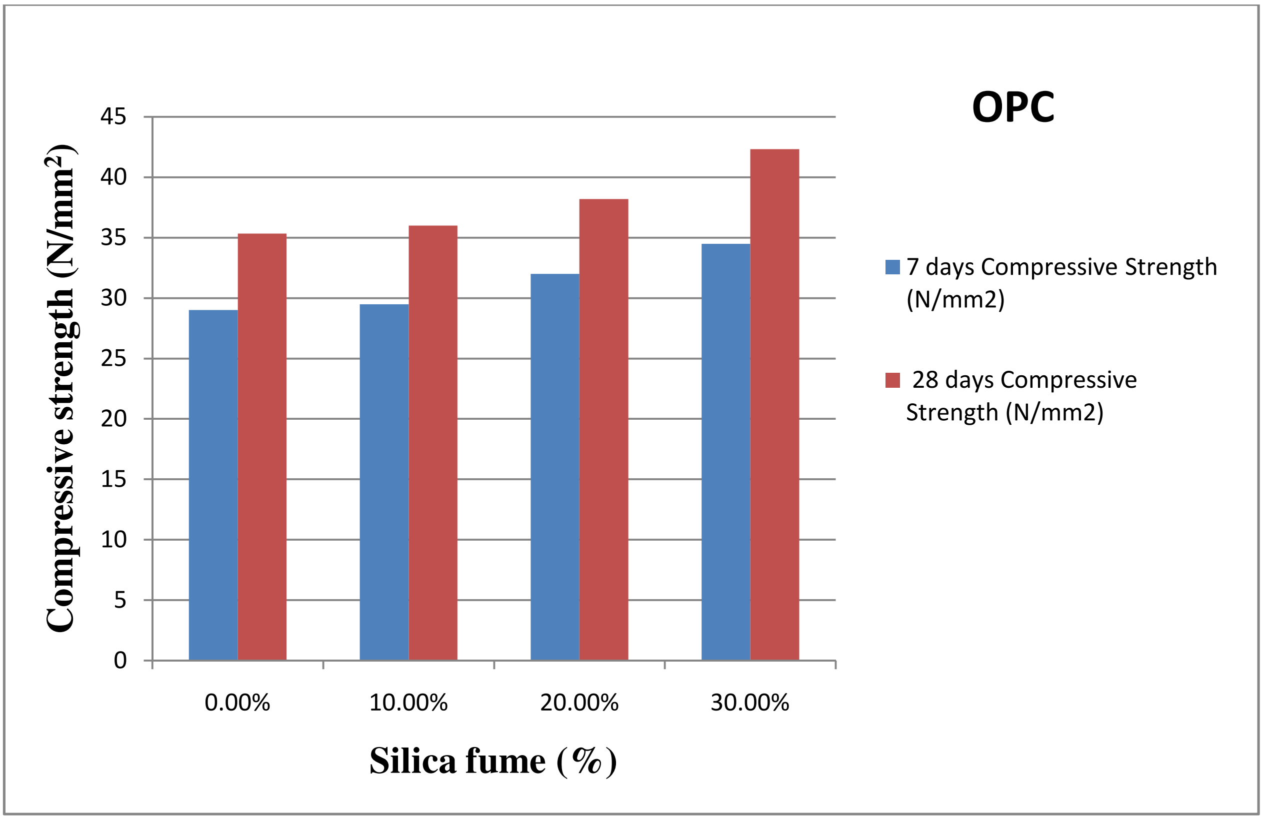

Fig. 4.20 Effect of silica fume on compressive strength at 0.2% fiber and OPC

Table 4.17. Effect of silica fume on splitting tensile strength using OPC:

Silica fume (%)	7 days splitting tensile strength (N/mm^2)	28 days splitting tensile strength (N/mm^2)
0.0(0%fibre)	**2.546**	**2.829**
10.0(0.2%fibre)	**2.687**	**3.253**
20.0(0.2%fibre)	**2.405**	**2.970**
30.0(0.2%fibre)	**2.263**	**2.829**

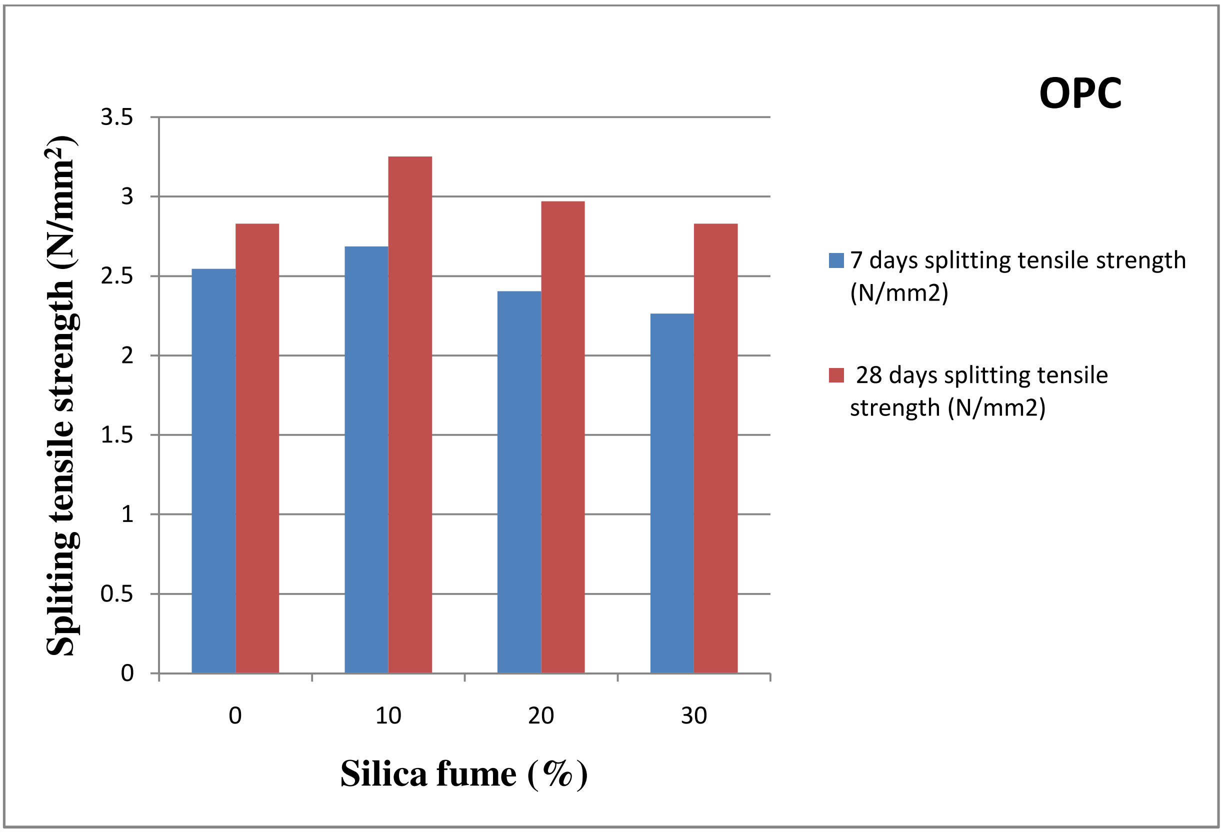

Fig. 4.21 Effect of silica fume on splitting tensile strength at 0.2% fiber and OPC

Table 4.18. Effect of silica fume on flexural strength using OPC:

Silica fume (%)	7 days flexural strength (N/mm^2)	28 days flexural strength (N/mm^2)
0.0 (0% fibre)	9.50	11.125
10.0(0.2%fibre)	7.875	9.00
20.0(0.2%fibre)	6.75	8.25
30.0(0.2%fibre)	6.04	6.875

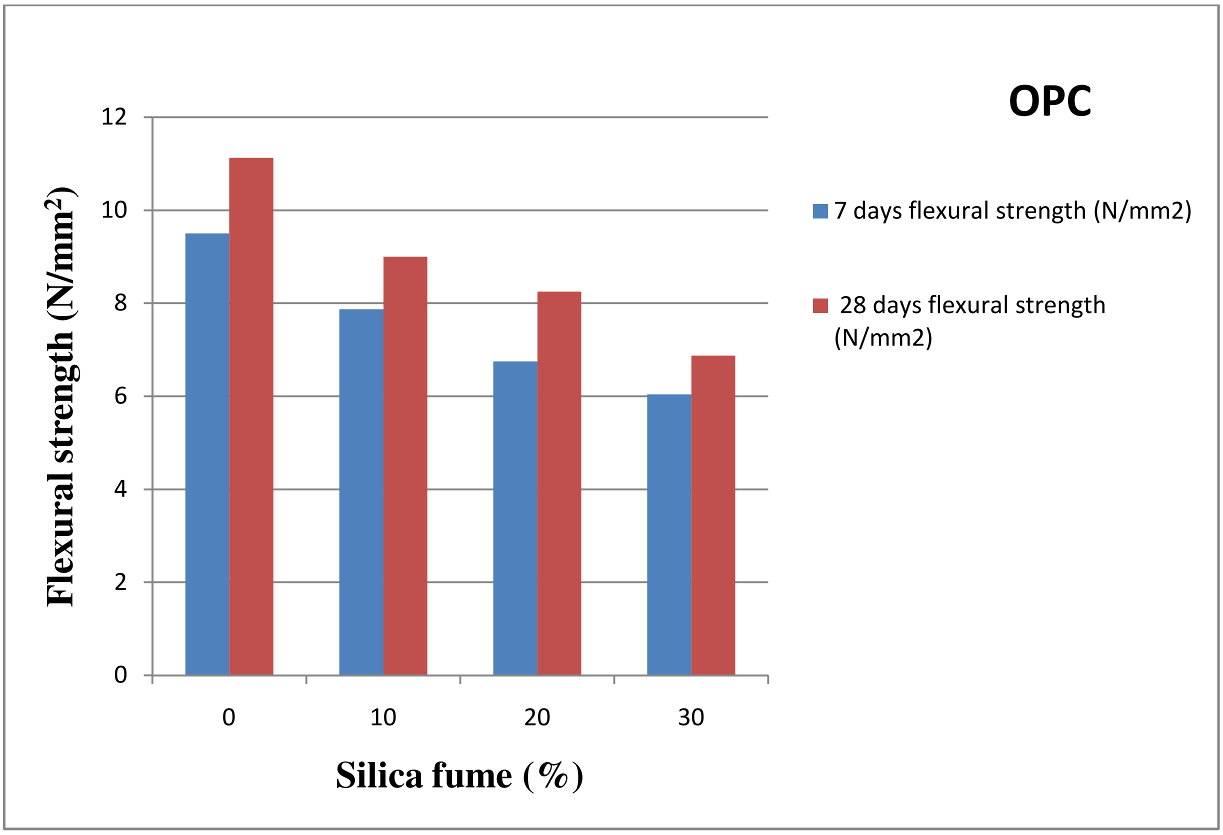

Fig. 4. 22 Effect of silica fume on flexural strength at 0.2% fiber and OPC

4.4.2. DISCUSSION:

Consistency of cement depends upon its fineness. Though silica fume having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases compare to plain cement. It was observed that normal consistency increases about 45% when silica fume percentage increases from 0% to 30%.

In case of Portland slag cement it was observed that using Recron fiber from 0.0% to 0.1% the compressive strength is not incresed, but as the fiber percentage was increased from 0.1% to 0.2% the compressive strength was increased and on further increament of fibre content the strength reduces. The 28 days compressive strength of concrete is higher at with 0.2% fiber compared to other fibre composition but lower than unreinforced concrete. In addition to fiber silica fume was used as a partial replacement to cement. The different percentage of silica fume such as 10%, 20%, 30% replacement was used with 0.2% Recron fiber. The 20% replacement of slag cement with of silica fume gave maximum strength compared to other percentages of replacement, whereas the strength is higer with 30%replacement of silica fume in case of ordinary Portland cement.

In case of Portland slag cement it was observed that addition of Recron fiber from 0.0% to 0.1% the splitting tensile strength decreases. But as the fiber percentage was increased that to 0.2% the 28 days splitting tensile strength is about 5% more than that of concrete without fiber. and with further addition of fiber the strength reduces. At 20% silica fume replacement to cement at 0.2% fiber content strength again increases about 12% more than that of normal concrete and maximum to other percentage of replacement, where as in case of ordinary Portland cement the tensile strength at 28 days is 15% more than normal concrete at 10% silica fume replacement and 0.2% fiber. The strength reduces gradually on other percentages of silica fume.

Flexural strength using Recron fiber from 0.0% to 0.1% is reducing. As the fiber percentage increases from 0.1%-0.2% the flexural strength is increasing about 5% and as further increasing the fiber content the strength decreases. In case of silica fume replacement at 0.2% fiber content the flexural strength gives positive outcome. At 20% silica fume there is higer strength about 10% more than normal concrete, which is the maximum strength than other percentages of silica fume replacement. In case of ordinary Portland cement keeping 0.2% fiber content and varying silica fume percent (10%, 20%, 30%) it was observed that the 28 days flexural strength decreases as the of silica fume percentage increases. The strength decreases about 40% at 30% silica fume replacement than normal concrete.

4.5. CAPILLARY AND POROSITY TEST:

Capillary and porosity test was conducted on specimens prepared with fiber and (fiber + silica fume) of Portland slag cement to observe the amount of water absorption and voids percentage present within the casted concrete.

Capillary test:

In case of capillary test cube specimen cured for 28 days were tested. Firstly the specimens were dried in oven at about 105^0C until constant mass was obtained. Specimens were cooled down to room temperature for 6hr. The sides of the specimen were coated with paraffin to achieve unidirectional flow. The specimens were exposed to water on one face by placing it on slightly raised seat (about 5 mm) on a pan filled with water. The water on the pan was maintained about 5mm above the base of the specimen during the experiment as shown in the figure below. The weight of the specimen was measured at regular 30 minutes interval up to 2hr 30 min to get the little absorption variation of water. The capillary absorption coefficient (k) was calculated by using formula:

$$\boldsymbol{k = \frac{W}{A \times \sqrt{t}}}$$

where,

W = Amount of water absorbed in gm

A = Cross sectional area in cm^2 contact with water

t = Time in seconds

The experimental set up is shown below,

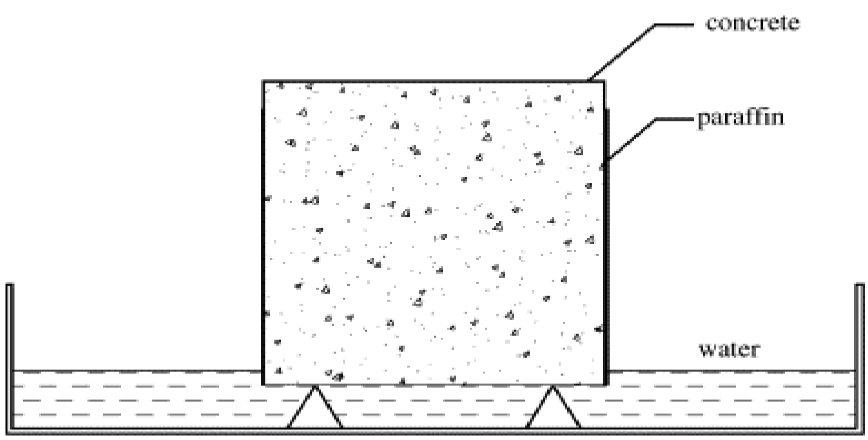

Fig. 4.23 Experimental set up for capillary absorption test

Firstly cubes with different percentage of fibers (0.0%,0.1%, 0.2%, 0.3%) are tested then secondly cubes of different silica fume percentage (10%, 20%, 30%) with constant 0.2% fiber were tested. All the specimens of Portland slag cement. The value of capillary absorption coefficient (k) was determined for different mixes.

Fig. 4.24 Capillary absorption test of cubes

Porosity test:

This test was conducted to evaluate the percentage of voids present in the specimens prepared. First of all saturated weights Wsat of the specimens cured for 28 days were obtained. Then specimens were dried in oven at about 105^0C until constant mass W_{dry} was obtained. Then weight of water absorbed Ww was calculated in grams, which was converted to cc. this signifies the volume of voids present within the specimen. The test was conducted on half cylinder of different mixes of Portland slag cement. Finally porosity η was calculated using the formula given below,

Porosity, $\boldsymbol{\eta} = {Vv}/{V} = {Wsat - Wdry}/{V} = {Ww}/{V}$

Where, Vv = volume of voids in cc

V = total volume of specimen in cc

4.5.1 TEST RESULT:

Table 4.19. Capillary absorption coefficient (k) for different fiber content:

Fiber %	Capillary absorption coefficient (k)
0.0	1.19×10^{-3}
0.1	1.31×10^{-3}
0.2	1.67×10^{-3}
0.3	3.57×10^{-3}

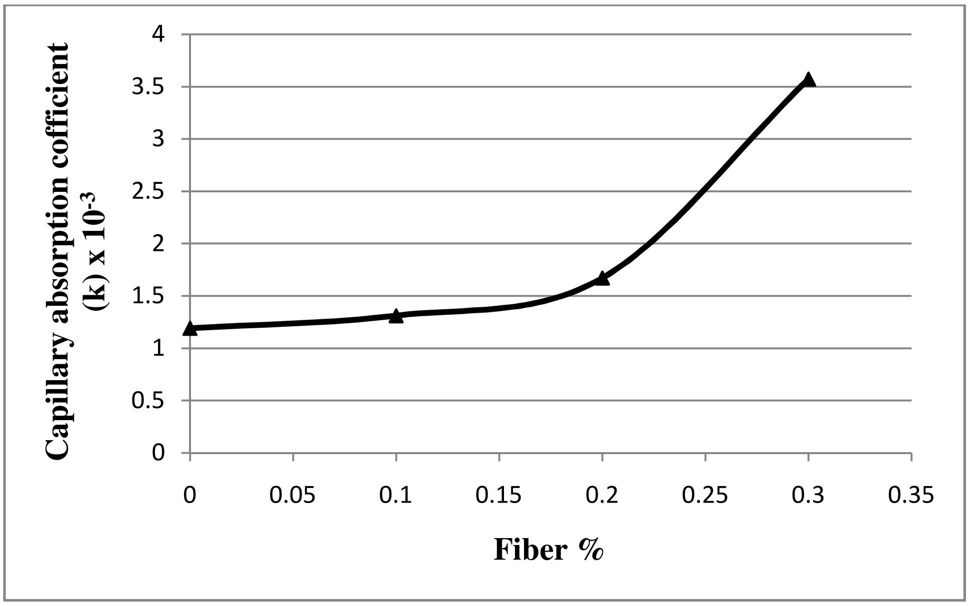

Fig. 4.25 Capillary absorption coefficient (k) for different fiber content

Table 4.20. Capillary absorption coefficient (k) for different SF content:

Silica fume%	Capillary absorption coefficient (k)
10	7.49×10^{-4}
20	5.62×10^{-4}
30	1.124×10^{-3}

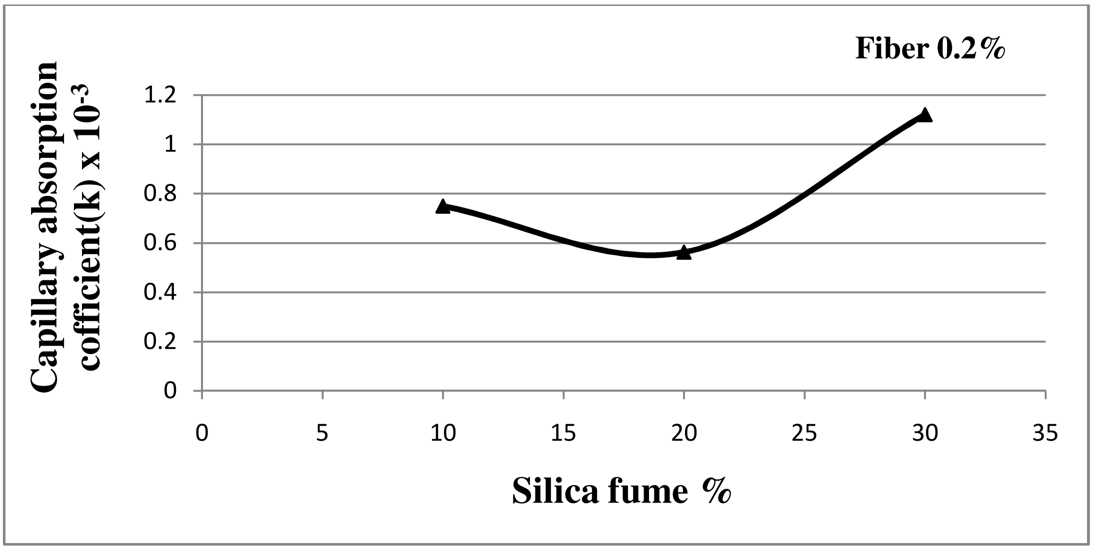

Fig. 4.26 Capillary absorption coefficient (k) of different SF content

Table 4.21. Porosity of different fiber mix:

Fiber %	Porosity , η
0.0	3.54
0.1	4.806
0.2	5.51
0.3	8.79

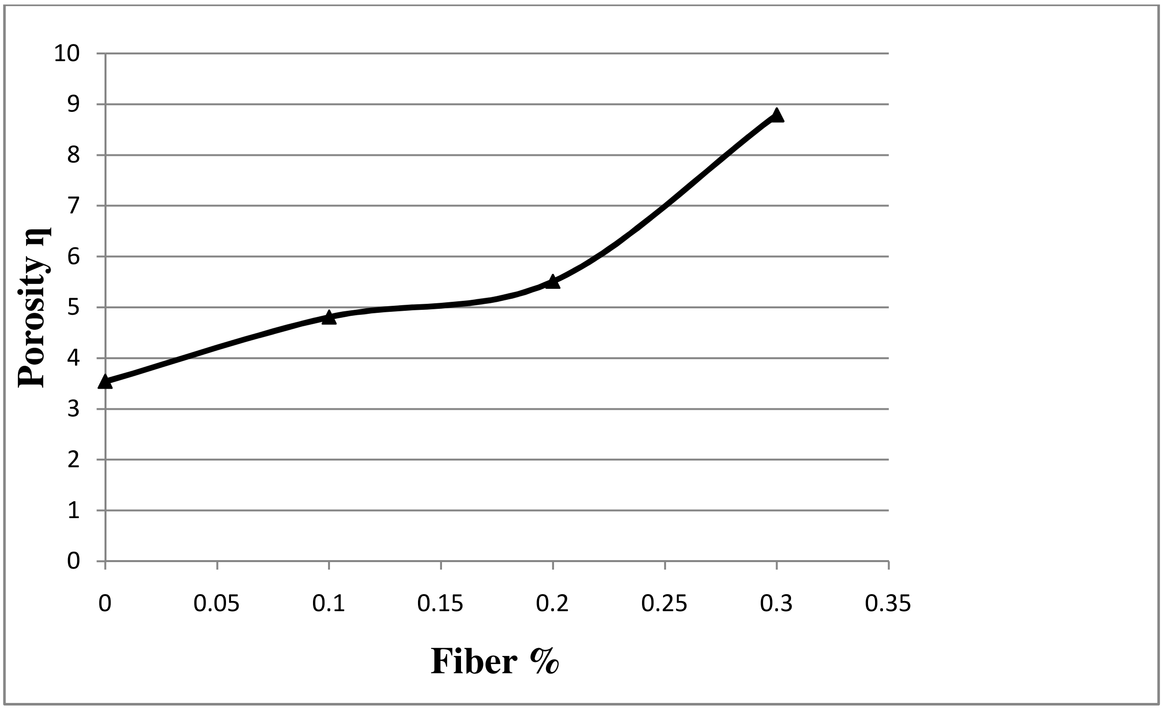

Fig. 4.27 Porosity of different fiber content

Table 4.22. Porosity of different Silica Fume mix:

Fiber %	Porosity , η
10	**5.54**
20	**5.03**
30	**4.89**

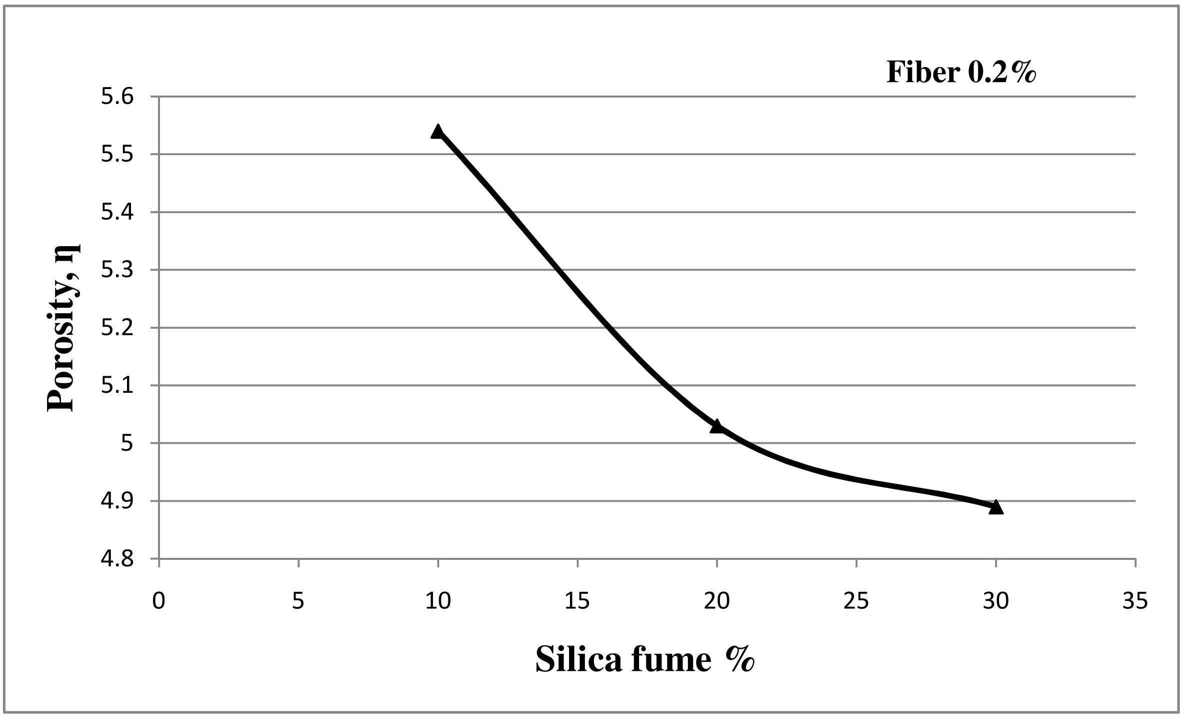

Fig. 4.28 Porosity of different SF content

4.5.2. DISCUSSION:

The capillary absorption coefficient is greatly influenced by the addition of silica fume in Recron fiber reinforced concrete. With 10% SF the capillary decreases by two times and at 20% SF the capillary decreases about 70% to capillary with 0.2% fiber only. Then at 30% SF it is increased slightly again.

The porosity of concrete decreases with silica fume. As the percentage of silica fume increases from 0 to 30% the porosity of concrete goes on decreasing. It was reduced about 12% that of fiber reinforced with 0.2% fiber.

CHAPTER 5

CONCLUSION

5.1. CONCLUSION:

In this present study with the stipulated time and laboratory set up an afford has been taken to enlighten the use of so called pozzolanic material like ground granulated blast furnace slag, rice husk and silica fume in fiber reinforced concrete in accordance to their proficiency. It was concluded that,

- Use of GGBS as cement replacement increases consistency. Although fineness greatly influenced on proper pozzolanic reaction still GGBS passing 75 micron sieve not giving good strength of mortar. Using GGBS more than 10% in Portland slag cement the strength reducing rapidly.
- With replacement of cement with RHA the consistency increases. Use of RHA which burned properly in controlled temperature improves the strength of mortar. But use of RHA not giving satisfactory strength result.
- With the use of superplasticizer it possible to get a mix with low water to cement ratio to get the desired strength.
- In case of Portland slag cement with the use of Recron fiber , the 28 days compressive strength at 0.2% fiber content the result obtained is maximum. The 28 days splitting tensile and flexural strength also increases about 5% at 0.2% fiber content to that of normal concrete. Further if fiber percentage increases then it was seen a great loss in the strength.
- As the replacement of cement with different percentages with Silica fume increases the consistency increases.
- With Portland slag cement keeping 0.2% Recron fiber constant and varying silica fume percentage the compressive, splitting tensile, flexural strength affected remarkably. Using 20% silica fume with 0.2% fiber percentage the 28 days compressive strength increases 7% more than concrete with 0.2% fiber only. 28days split tensile and flexural strength increases further, about 12% and 10% that of normal concrete.
- So it is inculcated that 0.2% Recron fiber and 20% SF is the optimum combination to achive the desired need.
- In case of OPC the compressive strength is increasing as the percentage of silica fume increases from 0-30% and 0.2% Recron fiber and it is about 20% more than strength of normal concrete with OPC.

- The splitting tensile strength increases about 15% at 10% SF and constant 0.2% Recron fiber, then decreases with increasing the SF percentage. Flexural strength is not giving good indication and goes on decreasing and it is about 40% decrement as the SF percentage increases to 30%.
- Ordinary Portland cement gives good compressive strength result as compared to Portland slag cement in case of mix with SF and 0.2% Recron.
- The capillary absorption coefficient (k) with decreases great sign as SF percentage increases at constant fiber percentage i.e 0.2%. At 20% SF content the k value decreases progressively with 70% reduction that to without SF content concrete.
- The porosity value also decreases as the SF value increases from 0-30% in Recron fiber reinforced concrete.

5.2. SCOPE OF FURTHER WORK:

The research work on pozzolanic materials and fiber along with pozzolanas is still limited. But it promises a great scope for future studies. Following aspects are considered for future study and investigation;

- Percentage and actual fineness of GGBS require as partial cement replacement for good strength development.
- Use of RHA as cement replacement with properly burned in controlled temperature and grinded which may lead proper strength development.
- Replacing cement with different percentage of silica fume to judge the optimum percentage of silica fume to be used to get better strength result.
- Research on Recron fiber and silica fume with greater fineness as a partial cement replacing material, by which we can minimise the cost and at the same time achieve the durability and strength for the production of High Performance Concrete.
- It requires a proper mixing propertions for the development of high strength, high performance concrete which may not be possible manually. So it needs some global optimisation techniques to develop the desire result with greater accuracy and time saving.

CHAPTER 6

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6.1. REFERENCES:

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6.2. APPENDIX:

Fig. Concrete Mixer

Fig. Slump test apparatus

Fig. Slump test

Fig.Vibrating machine

Fig. X-RD Machine